EJOSAT

ÖZEL SAYI/SPECIAL ISSUE 48
ŞUBAT/FEBRUARY 2023

EUROPEAN JOURNAL OF SCIENCE AND TECHNOLOGY

Avrupa Bilim ve Teknoloji Dergisi

1ST INTERNATIONAL CONFERENCE ON FRONTIERS IN ACADEMIC RESEARCH ICFAR, FEBRUARY 18-21, 2023

E-ISSN 2148-2683

https://dergipark.org.tr/en/pub/ejosat

EUROPEAN JOURNAL OF SCIENCE AND TECHNOLOGY

ÖZEL SAYI/SPECIAL ISSUE 48
ŞUBAT/FEBRUARY 2023

Prof. Dr. Osman SAĞDIÇ
Editor-in-Chief and Editor

Prof. Dr. Hüseyin TOROS
Editor

Prof. Dr. Ahmet DOĞAN
Editor

Editorial Board Members

Prof. Dr. Osman SAĞDIÇ
Subjects: Food Sciences and Engineering
Institution: Yildiz Technical University

Prof. Dr. Hüseyin TOROS
Subjects: Engineering
Institution: Istanbul Technical University

Prof. Dr. Ahmet DOĞAN
Subjects: Environmental Sciences and Engineering,Geological Sciences and Engineering,Civil Engineering
Institution: Yildiz Technical University

Prof. Dr. Osman TAYLAN
Subjects: Energy Systems Engineering,Machine Learning,Quality Management,Artificial Intelligence,Multiple Criteria Decision Making,Fuzzy Logic
Institution: Department of Industrial Engineering, Faculty of Engineering, King Abdulaziz University.

Prof. Dr. Tuncay GÜMÜŞ
Subjects: Food Sciences and Engineering
Institution: Namık Kemal University

Assoc. Prof. Dr. Juliana JALALUDIN
Subjects: Air Pollution and Control,Environmental Sciences and Engineering
Institution: Universiti Putra Malaysia, Faculty of Medicine and Health Sciences, Department of Environmental and Occupational Health

Asst. Prof. Dr. Abdulatef AHHMED
Subjects: Meat Technology
Institution: Aljfarah University

Prof. Dr. İskender AKKURT
Subjects: Physics,Computer Sciences and Engineering
Institution: Suleyman Demirel University

The European Journal of Science and Technology (EJOSAT) is a scientific and peer-reviewed journal published online four times in January, April, August, and November. The European Journal of Science and Technology is scanned in indexes such as Scilit, Index Copernicus, CiteFactor, International Innovative Journal Impact Factor, Eurasian Scientific Journal Index, SJIFactor, DRJI, Scientific Indexing Services and Google Scholar.

https://dergipark.org.tr/en/pub/ejosat

e-ISSN 2148-2683

ÖZEL SAYI/SPECIAL ISSUE 48
ŞUBAT/FEBRUARY 2023

İÇINDEKILER / TABLE OF CONTENTS

Rehabilitasyon Robotlarının Kontrolü için Bulanık Mantık ve PID Denetleyicinin Karşılaştırılması
Abdulhamit SEVGİ, Mustafa GÜNEŞ
Sayfa: 1 - 5

Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications
Yunus Emre KUŞİN, Merih PALANDÖKEN
Sayfa: 6 - 9

Thematic Park Congruence Analysis with Ecological Threshold Analysis Method, Case Study Çanakkale
Aylin ÇELİK TURAN, Murat ALTINOK
Sayfa: 10 - 18

Mültecilere Yönelik Nefret Söyleminin Tespitinde Makine Öğrenmesi Modellerinin Kullanılması
Figen EĞİN, Vahide BULUT
Sayfa: 19 - 22

Random Forest Importance-Based Feature Ranking and Subset Selection for Slope Stability Assessment using the Ranger Implementation
Selçuk DEMİR, Emrehan Kutlug SAHİN
Sayfa: 23 - 28

Sensing Magnetic Field with Single-Spin Dynamical Probe State: Control over Sensing Precision via Quantum Fisher Information
Sergey BORİSENOK
Sayfa: 29 - 33

Baghdad Vehicle Traffic Congestion: Case Study
Salim MOHAMMED ALİ, Emad AL-HEMİARY
Sayfa: 34 - 39

Obtaining Pectin Reinforced Polyester Composite and Investigation of Thermophysical Properties
Mukaddes KARATAŞ, Ercan AYDOĞMUŞ
Sayfa: 64 - 66

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 1-5, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 1-5, February 2023
Copyright © 2023 EJOSAT
Research Article

Rehabilitasyon Robotlarının Kontrolü için Bulanık Mantık ve PID Denetleyicinin Karşılaştırılması

Abdulhamit Sevgi[1*], Mustafa Güneş [2]

[1*] OSTİM Teknik Üniversitesi, Meslek Yüksekokulu, Elektronik ve Otomasyon Bölümü, Ankara, Türkiye, (ORCID: 0000-0003-3567-848X), abdulhamit.sevgi@ostimteknik.edu.tr
[2] OSTİM Teknik Üniversitesi, Meslek Yüksekokulu, Elektronik ve Otomasyon Bölümü, Ankara, Türkiye, (ORCID: 0000-0002-0266-6370), mustafa.gunes@ostimteknik.edu.tr

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1251862)

ATIF/REFERENCE: Sevgi, A., Güneş, M. (2023). Rehabilitasyon Robotlarının Kontrolü için Bulanık Mantık ve PID Denetleyicinin Karşılaştırılması. *Avrupa Bilim ve Teknoloji Dergisi*, (48), 1-5.

Öz

Doğrusal olmayan bir sistemin yanıtı genellikle bir doğrusal denetleyici kullanılarak istenen bir modele göre şekillendirilemez. PID denetleyiciler gibi geleneksel model tabanlı doğrusal denetleyicilerle doğrusal olmayan durumların gerçekleştirilmesi zordur ve denetleyicinin düzgün çalışması için sıfırlama önleyici sarma, geciktirilmiş integral eylem vb. gibi birçok ek önlem dahil edilmelidir. Bu nedenle doğrusal olmayan sistemler için genellikle Bulanık Mantık Kontrol gibi kontrol yöntemleri kullanılır. Bulanık Mantık, gömülü kontrol için hem doğrusal hem de doğrusal olmayan sistemlerin geliştirilmesinde uygulanabilen alternatif bir tasarım metodolojisidir. Tasarımcılar, bulanık mantık kullanarak daha düşük geliştirme maliyetleri, üstün özellikler ve daha iyi son ürün performansı sağlayabilirler. Bu sebeple bu çalışmada rehabilitasyon robotlarının kontrolü için MATLAB/Simulink ortamında bir Bulanık Kontrol denetleyici tasarlanmıştır. Daha sonra kontrol etkisi analiz edilip PID denetleyicinin etkisiyle karşılaştırılmıştır. Karşılaştırma sonucunda bulanık mantık denetleyici, PID kontrolünden özellikle yanıt süresi, kararlı durumdaki hata ve aşım gibi çeşitli parametrelerde daha üstün performans sergilemiştir.

Anahtar Kelimeler: PID, Bulanık Mantık, Doğrusal Kontrol, Doğrusal Olmayan Kontrol, Rehabilitasyon Robotu.

Comparison of Fuzzy Logic and PID Controller for Control of Rehabilitation Robots

Abstract

The response of a nonlinear system cannot usually be shaped into a desired model using a linear controller. Non-linear situations are difficult to realize with traditional model-based linear controllers such as PID controllers, and anti-reset winding, delayed integral action, etc., are required for the controller to work properly. Many additional measures should be included, such as for this reason, control methods such as Fuzzy Logic Control are often used for nonlinear systems. Fuzzy Logic is an alternative design methodology that can be applied to the development of both linear and nonlinear systems for embedded control. By using fuzzy logic, designers can achieve lower development costs, superior features, and better end-product performance. For this reason, in this study, a Fuzzy Control controller was designed in MATLAB/Simulink environment for the control of rehabilitation robots. Then the control effect was analyzed and compared with the effect of the PID controller. As a result of the comparison, the fuzzy logic controller outperformed the PID control in various parameters such as response time, steady state error and overshoot.

Keywords: PID, Fuzzy Logic, Linear Control, Non-Linear Control, Rehabilitation Robot.

1. Giriş

Geleneksel olarak, rehabilitasyon süreci büyük ölçüde terapistin deneyimine ve manuel manipülasyonuna dayanır. Rehabilitasyon süreci zaman alıcıdır ve felçli hastaların artmasıyla birlikte tedavi için yeterli terapist bulunmamaktadır. Dünya Sağlık Örgütü'nün (WHO) raporuna göre, 2030 yılına kadar 23,3 milyondan fazla insanın kronik hastalıklardan muzdarip olma şansı olacağı tahmin edilmektedir (Satoh vd., 2009). Bu nedenle, rehabilitasyon robotik sistemi bu karmaşık problem için en iyi çözümlerden biri olacaktır. Rehabilitasyon robotiklerinin uygulamaları sınırlı kalmayıp insan gücü artırma ve insan hareket yardımı şeklinde uygulanabilir.

Rehabilitasyon robotik sistemi esas olarak aktif ve pasif tipe ayrılır. Pasif tip rehabilitasyon robotik sistemi, hastanın tanımlanan egzersizi yapmasına tam olarak yardımcı olur. Rehabilitasyon egzersizlerini etkili bir şekilde gerçekleştirmek için kesin, kararlı ve güvenilir kontrol teknikleri gereklidir. Geleneksel PID denetleyici, sağlamlık, basitlik ve geniş uygulanabilirlik gibi birçok iyi özelliğinden dolayı yaygın olarak kullanılmaktadır. Robotla gerçekleştirilen rehabilitasyon sürecinde hasta da dinamik sistemin bir parçasıdır ve hastanın/deneğin dinamik modeli robot dinamik modeli kadar değişmez ve net değildir. Bu nedenle, rehabilitasyon robotunun uygun şekilde kontrol edilmesi kolay bir iş değildir, çünkü harici bozukluğun kendisi, başka bir çözülmemiş kontrolör olan insan müdahalesine maruz kalır. Bu nedenle bulanık mantık kontrolcü kontrolü (FLC) tercih edilmesi daha uygun görülmektedir (Ali vd., 2018). Klasik mantığın benzer durumlarda problemlere yol açması ve insan mantığına benzer çalışamaması nedeniyle ilk kez 1965 yılında matematiksel düşünce Lotfi A. Zadeh tarafından ortaya atılmıştır (Wang, 1993). Bulanık mantık, çalışma prensibi insanın karar ve düşünce mekanizmasına benzer olması sebebiyle belirsiz durumlarda tutarlı ve doğru karar verebilmektedir. Bir sistemin karmaşıklığı arttıkça kesin bir model yapmak daha zor ve bazen imkânsız hale gelir. Bulanık Mantık aynı zamanda bir problem çözme kontrol sistemi metodolojisi olarak kabul edilir. Donanım, yazılım veya her ikisinin bir kombinasyonu olarak uygulanabilir.

Zadeh 1973'te bulanık mantığı önerdikten sonra dilsel bir değişken kavramını tanıttı. Bulanık mantık, geleneksel mantık sisteminden farklı olarak, hatalı veya kesin olmayan modelleri modelleyebilmektedir. Bulanık mantık yaklaşımı, geleneksel tekniklere göre büyük avantajlar sağlayan daha basit, daha hızlı ve daha güvenilir bir çözüm sunmuştur (Ozkaya, 2016). Bulanık Mantık, çok sayıda kontrol uygulamasına başarıyla uygulanmıştır. En sık kullanılan denetleyici, sistemin matematiksel bir modelini gerektiren PID denetleyicisidir. Bulanık mantık denetleyici, PID denetleyiciye bir alternatif sunar. Bulanık mantık denetleyicilerdeki kontrol eylemi, basit "eğer-o zaman" kuralları ile ifade edilebilir. Bulanık denetleyiciler, klasik denetleyicilere göre çok daha geniş çalışma koşullarını kapsayabildikleri ve farklı nitelikteki gürültü ve parazitlerle çalışabildikleri için klasik denetleyicilere göre daha yeterli olduğu çeşitli çalışmalarla ispat edilmiştir (Obaid vd., 2010).

Kontrol sistemlerinde ilk uygulama, küçük model bir buhar motoru için FLC'nin uygulanabilirliğini gösteren Mamdani tarafından 1974'te başarılmıştır (Mamdani, 1974). FLC'nin matematiksel temeli, bulanık sistemlerin evrensel yaklaştırıcı olduğunu gösteren Wang tarafından sağlanmıştır (Wang, 1994). Bulanık mantığın başarıyla uygulandığı en karmaşık ilk sistemlerden biri de 1977 yılındaki çimento fırınlarıdır (Kadirkamanathan, 1999). 1985 yılında Sugeno ve Murakami'nin yaptıkları bulanık mantık kontrolör çalışması otonom araç kontrolünde dönüm noktası olmuştur. Bulanık mantık ile otonom park kontrolü yapan çalışmalarıyla, bir makinenin basit bir insan işlemi ve deneyiminin modeli ile kontrol edilebileceğini ispatlamışlardır (Sugeno & Murakami, 1984). Otonom kontrol, bir sürücü deneyimine dayanarak, doğru kontrol kurallarını bulmaya ve uygun ayarların yapılmasına kadar indirgenmiştir. Bunun sonucunda yapılan çalışmalarda, otonom araçlarda klasik kontrol ve bulanık kontrol tekniklerini karşılaştırmıştır ve bulanık denetleyicilerin başarılı olduğu gözlenmiştir (Chaib vd., 2004).

Achkoski vd., hastanın sağlık durumunu değerlendirmek ve belirli bir ölçeğe göre sıralamak için fizyolojik parametrelerin (kalp hızı, sistolik kan basıncı ve vücut ısısı gibi) analizi için bulanık mantık temelli bir yaklaşım önermişlerdir (Achkoski vd., 2016). Wei vd., Tip-2 kendini organize eden bulanık mantık denetleyicisi (SOFLC), operasyonel belirsizliklerle mücadele ederken çevrimiçi eğitimi kolaylaştırmak için tip-2 bulanık mantık denetleyicisini kendi kendini organize eden bir mekanizma ile birleştirmişlerdir. Hastalar arası değişkenliği ele almak için tip-2 SOFLC parametrelerini çevrimdışı olarak optimize etmek için yeni bir veriye dayalı vekil model ve genetik programlamaya dayalı strateji geliştirmişlerdir (Wei vd., 2020). Sagdatullin, petrol üretimi ve nakliyesinde teknolojik nesneler için otomatik kontrol sistemlerinin inşasına yönelik çeşitli yaklaşımların özelliklerini incelemiştir. Ele alınan sistemin tanımlama modelleri araştırılması sonucunda doğrusal olmayan nesneleri kontrol etmek için ayrık terimli nöro-bulanık ve bulanık kontrolörlerin kullanılmasının gerekli olduğu sonucuna varılmıştır (Sagdatullin, 2021).

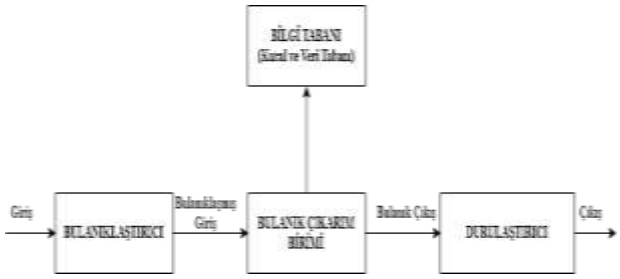
Y. Jianhua vd., buhar enjeksiyon kazanı için tahmine dayalı bulanık kontrol sisteminin bir uygulamasını sunmuştur (Jianhua vd., 2006). Yawei Zhao vd., bulanık ve yapay sinir ağı kavramlarını entegre etti ve bir kazan sisteminde arıza teşhisi için uygulamışlardır (Zhao vd., 2008). R. Liu vd., bulanık uyarlamalı PID (Orantılı-İntegral-Türev) ve kademeli kontrol kavramlarını birleştirdi ve bunu fırın sıcaklık kontrolüne uygulamışlardır (Liu vd., 2020). M. Raghappriya vd., bulanık mantığa dayalı fotovoltaik sistem takibi üzerine bir çalışma yapmışlardır (Raghappriya vd., 2022). Dr. V. Suma, bulanık mantık ve derin sinir ağının hibrit kombinasyonuna dayanan bir bilgi erişim sistemi sunmuştur (Suma, 2020). Namazov MATLAB paket programında 2-bağlantılı robot manipülatörünün bulanık mantık kontrolü için sistem tasarımı gerçekleştirmiştir (Namazov, 2018).

Bu çalışmada ise rehabilitasyon uygulamalarında kullanılan bir robotik manipülatörün simüle edilerek geleneksel bir PID denetleyicisi ile bir bulanık mantık denetleyicisi arasındaki karşılaştırmaları içerir.

2. Materyal ve Metot

Bulanık denetleyicinin dört ana bileşeni vardır: Birinci bölüm, bilginin bir dizi kural biçiminde tutulduğu "kural tabanı"dır. İkinci kısım, değerlendirmelerin yapıldığı, o an hangi kontrol kurallarının ilgili olduğu ve ardından tesise hangi girdinin verilmesi gerektiğine karar verilen "çıkarım mekanizması"dır. Üçüncü kısım, "bulanıklaştırma"nın girdileri basitçe değiştirerek yorumlanabilmesi ve kural tabanındaki kurallarla karşılaştırılabilmesidir. Bir bulanık denetleyicinin son kısmı, çıkarım mekanizması tarafından kararlaştırılan bulanık çıktıları

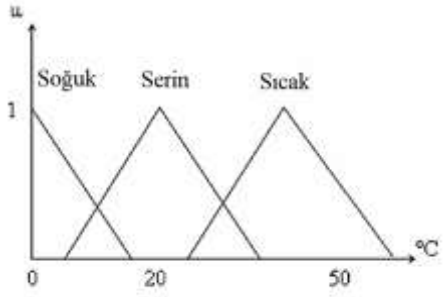
tesise kesin girdilere dönüştüren "durulaştırma"dır. Bulanık denetleyicinin temel blok diyagramı Şekil 1'de verilmektedir.



Şekil 1. Bulanık denetleyici temel blok diyagramı.

Bulanıklaştırma; Bulanıklaştırma, bulanık çıkarım sürecinin ilk adımıdır. Bu, kesin girdilerin bulanık girdilere dönüştürülmesini içerir. Kesin girdiler, sensörler tarafından ölçülen sıcaklık, basınç, rpm vb. gibi verileri işlenmek üzere kontrol sistemine iletilen giriş kısmıdır.

Bulanık çıkarım birimi tarafından işlenecek olan her net girdinin kendi üyelik fonksiyonları veya kümeleri grubu vardır. Bu üyelik fonksiyonları grubu, kesin girdinin sahip olabileceği tüm ilgili değerleri içeren bir söylem evreni içinde bulunur. Şekil 2'de hava sıcaklığının kesin değerlerini bulanıklaştırmak için üç bulanık küme tanımlanmıştır. Bu takımlar diğer takımları kısmen kapsar. Bu nedenle, bazı net girdiler farklı bulanık kümelerin üyesi olabilir. Ancak her girdinin farklı üyelik dereceleri vardır. Bu üyelik dereceleri kontrol süreçlerinde değerlendirilir.



Şekil 2. Hava sıcaklığının üyelik fonksiyonları.

Kural tabanı; Kurallar, kuralların hem koşulunda hem de sonucunda birkaç değişken kullanabilir. Bu nedenle kontrolörler hem çok girişli çok çıkışlı (MIMO) problemlere hem de tek girişli tek çıkışlı (SISO) problemlere uygulanabilir. Tipik SISO problemi, bir hata sinyaline dayalı olarak bir kontrol sinyalini düzenlemektir. Kontrolör aslında hem hataya hem de hatadaki değişime ve entegre hataya girdi olarak ihtiyaç duyabilir, çünkü prensipte üçü de hata ölçümünden oluşur. Basitleştirmek için kontrol hedefi, bazı proses çıktılarını önceden belirlenmiş bir ayar noktası veya referans etrafında düzenlemektir. Temel olarak bir linguistic denetleyicisi, IF-THEN formatında kurallar içerir.

- Hata Negatif ise ve hatadaki değişiklik Negatif ise, çıktı Negatif Büyük olur
- Hata Negatif ise ve hatadaki değişim Sıfır ise, çıkış Negatif Orta olur
- Hata Negatif ise ve hatadaki değişim Pozitif ise, çıkış Sıfırdır
- Eğer hata Sıfır ve hatadaki değişim Negatif ise çıkış Negatif Orta olur.

Verilen bu kurallar Tablo 1'deki gibi kural tablosu formatında sunulabilir.

Tablo 1. Kurallar Tablosu.

	Hatadaki Değişim			
Hata		N	Z	P
	N	NB	NM	Z
	Z	NM	Z	PM
	P	Z	PM	PB

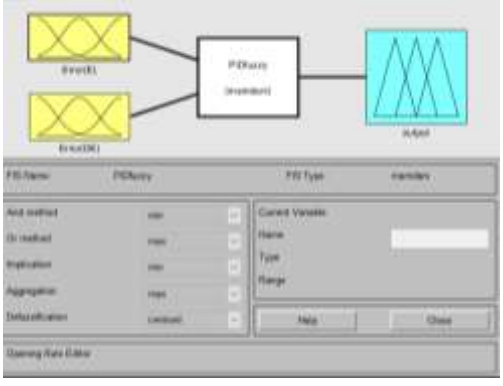
Çıkarım mekanizması; Çıkarım mekanizmasının iki temel görevi vardır: Birincisi, her bir kuralın mevcut durumla ilgili olma derecesini belirlemektir. Bulanıklaştırma aşamasından geçen girdiler, kural tabanındaki her kural için değerlendirilir. Girdilere bağlı olarak, bir veya daha fazla kural karşılanabilir. Diğer görev, mevcut girdileri ve kural tabanındaki bilgileri kullanarak kontrol eylemine karar vermektir. Çıkarım mekanizmasının çıktısı, durulaştırma aşamasının girdisi olur.

Durulaştırma; Çıkarım mekanizmasının çıktısı, durulaştırma aşamasının girdisidir. Bulanık değerlere sahip karar verilen kontrol eylemi, durulaştırma yöntemleri yardımıyla kesin değerlere dönüştürülür. Bulanık değerleri durulaştırmanın birçok yöntemi vardır. Sonucun "kütle merkezi"nin kesin değeri sağladığı "centroid" yöntemi çok popülerdir. Diğer bir yaklaşım ise en çok katkıda bulunanın değerini alan "yükseklik" yöntemidir.

Bu çalışmada robot kolun transfer fonksiyonu, SolidWorks'te Newton Euler yöntemine dayalı olarak 3 boyutlu model üst ekstremite rehabilitasyon robotu tasarımının .xml dosyasını MATLAB Simscape Multibody'ye aktarılarak elde edilmiştir. Giriş olarak gerilim ve çıkış olarak konum alınarak ortaya çıkarılan transfer fonksiyonu denklem 1' verilmiştir.

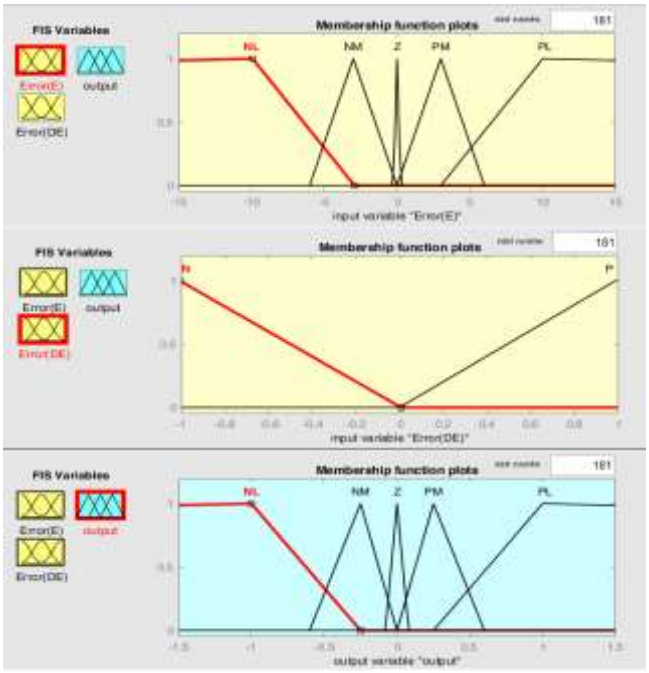
$$\frac{Konum}{Gerilim} = \frac{0.0718}{0.0536*s^2 + 0.003767*s + 0.005651} \quad \text{Denklem (1)}$$

Tasarlanan bulanık denetleyici için iki giriş tanımlanmıştır. Birincisi step adım girişinden hatanın çıkarılmış halidir. İkincisi bu eşitliğin türevidir. Bu Girdilerin her ikisi de kural tabanına uygulanır. Kural tabanında yazılan kurallara göre, denetleyici harekete geçer ve denetleyicinin çıkışı olan ve "aktüatör" hareket eder. Şekil 3'te genel "fis" editörü ekranı verilmektedir.



Şekil 3. Mamdani tipi bulanık denetleyici.

Üyelik İşlevi Düzenleyicisi, FIS Düzenleyicisi ile bazı özellikleri paylaşır. Aslında, beş temel GUI aracının tümü benzer menü seçeneklerine, durum satırlarına, yardım ve kapat düğmelerine sahiptir. Üyelik Fonksiyon Düzenleyicisi, tüm bulanık çıkarım sistemi için tüm giriş ve çıkış değişkenleriyle ilişkili tüm üyelik fonksiyonlarını görüntülemenizi ve düzenlemenizi sağlayan araçtır. Şekil 4'te tasarlanan bulanık denetleyiciye ait üyelik fonksiyonları verilmektedir.



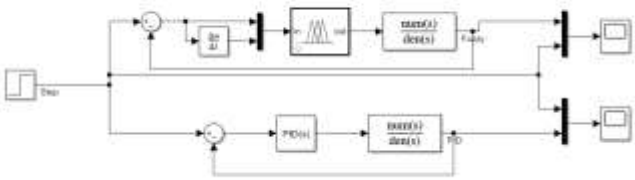
Şekil 4. Tasarlanan denetleyiciye ait giriş ve çıkış üyelik fonksiyonları.

Grafik Kural Düzenleyici arayüzünü kullanarak kural tabanı oluşturmak oldukça kolaydır. FIS Düzenleyicisi ile tanımlanan girdi ve çıktı değişkenlerinin açıklamalarına dayalı olarak, kural düzenleyici, her girdi değişkeni kutusunda bir öğeyi, her çıktı kutusunda bir öğeyi seçerek kural ifadelerini otomatik olarak oluşturmanıza olanak tanır. Tasarlanan bulanık denetleyicinin kural tabanı Şekil 5'te gösterildiği gibidir.

1. If (Error(E) is PL) then (output is PL) (1)
2. If (Error(E) is NL) then (output is NL) (1)
3. If (Error(E) is Z) and (Error(DE) is N) then (output is NM) (1)
4. If (Error(E) is Z) and (Error(DE) is P) then (output is PM) (1)
5. If (Error(E) is Z) then (output is Z) (1)
6. If (Error(E) is NM) then (output is NM) (1)
7. If (Error(E) is PM) then (output is PM) (1)

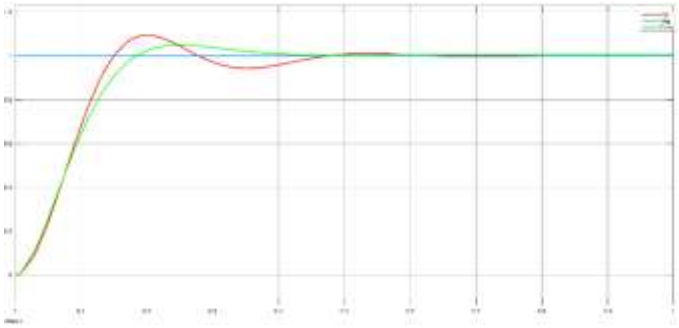
Şekil 5. Tasarlanan bulanık denetleyicinin kural tabanı.

Tasarlanan bulanık mantık ve PID denetleyici MATLAB Simulink ekran görüntüsü Şekil 6'da verilmektedir.



Şekil 6. Tasarlanan bulanık mantık ve PID denetleyicilerin simülasyon ortamında gösterimi.

Tasarlanan kontrolörlerin simülasyon çıktıları şekil 7'de verilmektedir.



Şekil 7. Tasarlanan bulanık mantık ve PID denetleyicilerin simülasyon sonuçları.

Simülasyon sonuçlarında istenen seviye için bulanık ve PID denetleyici geçici yanıtının karşılaştırmasını gösterilmektedir (Kırmızı çizgi PID yanıtını, yeşil çizgi bulanık yanıtı ve mavi olan istenen düzeyi gösterir). Grafikten, PID denetleyicinin bulanık denetleyiciye kıyasla büyük bir aşmaya sahip olduğu ve ayrıca istenen seviyede sabitlenmesinin çok zaman aldığı açıktır. Bulanık mantık ise az aşıma ve sabit durum hatasına sahiptir ve doğru seviye kontrolü sağlayarak hızlı bir şekilde dengelenir. PID kontrolünün ve bulanık kontrolün avantaj ve dezavantajlarının birbirini dengelediğini bulduk. Hızlı kontrol (kaba ayar) için bulanık denetleyici kullanabilir ve ardından doğru kontrol (ince ayar) için PID denetleyici kullanabiliriz. Bu yöntem kullanılarak çeşitli kontrolör tasarımları geliştirilmiştir (Kumar, 2015; Bhimte vd., 2018; Bharti vd., 2018; Santos vd., 1996).

3. Sonuç

Çalışmanın Simülasyon sonuçlarına bakıldığında geliştirilen FLC'nin rehabilitasyon robotlarına uygulanabilirliği ispatlanmıştır. Geliştirilen FLC üretilen salınımlar ve aşma açısına bakıldığında yaygın olarak kullanılan klasik PID tasarım yöntemine göre daha iyi performans göstermektedir. Simülasyon sonuçlarında görüldüğü üzere PID denetleyici yükselme süresi daha azdır ancak üretilen salınımlar ve aşım ve oturma süresi daha fazladır. Ancak bulanık mantık denetleyici durumunda, salınımlar, aşma ve oturma süresi düşüktür. Bu nedenle süreçte salınımların tolere edilemediği durumlarda FLC uygulanabilir. FLC, dinamikleri önemli ölçüde değişen tesisler için güçlü performans sergiler. Bu iki sistemden elde edilen kontrol yanıtının karşılaştırılması, bulanık mantık denetleyicinin aşımı ve sabit durum hatasını önemli ölçüde azalttığını göstermiştir. Bulanık Mantık yöntemi, sistemin nasıl çalıştığını anlamaya çalışmak yerine sistemin ne yapması gerektiğine odaklanmaktadır. Bu sayede sistemi matematiksel olarak modellemeye çalışmak yerine

sorunun çözümüne odaklanılması daha hızlı, daha ucuz çözümlere yol açabilir.

Kaynakça

Achkoski, J., Temelkovski, B., & Stainov, R. (2016). Fuzzy logic controller development for classification of patient status based on physiological parameters. 2016 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom), 1-5.

Ali, A., Ahmed, S.F., Kadir, K.A., Joyo, M.K., & Yarooq, R.N. (2018). Fuzzy PID controller for upper limb rehabilitation robotic system. 2018 IEEE International Conference on Innovative Research and Development (ICIRD), 1-5.

Bharti, R., Trivedi, R., & Padhy, P.K. (2018). Design of Optimized PID Type Fuzzy Logic Controller for Higher Order System. 2018 5th International Conference on Signal Processing and Integrated Networks (SPIN), 760-764.

Bhimte, R., Bhole, K., & Shah, P. (2018). Fractional Order Fuzzy PID Controller for a Rotary Servo System. 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI), 538-542.

Chaib, S., Netto, M.S., & Mammar, S. (2004). H/sub /spl infin//, adaptive, PID and fuzzy control: a comparison of controllers for vehicle lane keeping. IEEE Intelligent Vehicles Symposium, 2004, 139-144.

Jianhua, Y., Wenqi, L., & Wei, L. (2006). Fuzzy Predictive Control of Steam Dryness for Steam-injection Boiler. 2007 Chinese Control Conference, 395-398.

Kadirkamanathan, V. (1999). Fuzzy Logic and Control: Software and Hardware Applications. Mohammad Jamshidi, Nader Vadiee and Timothy J. Ross (eds.). Artificial Intelligence Review, 13, 337-339.

Kumar, R., & Kumar, M. (2015). Improvement power system stability using Unified Power Flow Controller based on hybrid Fuzzy Logic-PID tuning In SMIB system. 2015 International Conference on Green Computing and Internet of Things (ICGCIoT), 815-819.

Liu, R., Hu, E., Zhu, Z., Mao, L., & Ma, Z. (2020). Study on temperature control system of ceramic kiln based on fuzzy PID cascade. 2020 IEEE 4th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), 1, 1769-1772.

Mamdani, E.H. (1974). Applications of fuzzy algorithms for control of a simple dynamic plant. Proceedings of the IEEE.

Namazov, M. (2018). Fuzzy Logic Control Design for 2-Link Robot Manipulator in MATLAB/Simulink via Robotics Toolbox. 2018 Global Smart Industry Conference (GloSIC), 1-5.

Obaid, Z.A., Sulaiman, N.B., Marhaban, M.H., & Hamidon, M.N. (2010). Analysis and Performance Evaluation of PD-like Fuzzy Logic Controller Design Based on Matlab and FPGA.

Ozkaya, U. and Seyfi, L., (2016), A novel fuzzy logic model for intelligent traffic systems, Electronics World, 122(1960), 36-39.

Raghappriya, M., Devadharshini, K.M., & Karrishma, S. (2022). Fuzzy Logic Based Maximum Power Point Tracking of Photovoltaic System. Journal of Innovative Image Processing.

Sagdatullin, A.M. (2021). Application of Fuzzy Logic and Neural Networks Methods for Industry Automation of Technological Processes in Oil and Gas Engineering. 2021 3rd International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency (SUMMA), 715-718.

Santos, M., Dormido, S., & de la Cruz, J. (1996). Fuzzy-PID controllers vs. fuzzy-PI controllers. Proceedings of IEEE 5th International Fuzzy Systems, 3, 1598-1604 vol.3.

Satoh, H., Kawabata, T., & Sankai, Y. (2009). Bathing care assistance with robot suit HAL. 2009 IEEE International Conference on Robotics and Biomimetics (ROBIO), 498-503.

Sugeno, M., & Murakami, K. (1984). Fuzzy parking control of model car. The 23rd IEEE Conference on Decision and Control, 902-903.

Suma, V. (2020). A Novel Information retrieval system for distributed cloud using Hybrid Deep Fuzzy Hashing Algorithm. September 2020.

Wang, L. (1992). Stable adaptive fuzzy control of nonlinear systems. [1992] Proceedings of the 31st IEEE Conference on Decision and Control, 2511-2516 vol.3.

Wang, L. (1994). Adaptive fuzzy systems and control- design and stability analysis.

Wei, Z., Doctor, F., Liu, Y., Fan, S., & Shieh, J.S. (2020). An Optimized Type-2 Self-Organizing Fuzzy Logic Controller Applied in Anesthesia for Propofol Dosing to Regulate BIS. IEEE Transactions on Fuzzy Systems, 28, 1062-1072.

Zhao, Y., Chen, L., & Yang, Q. (2008). The research on the fault diagnosis for boiler system based on fuzzy neural network. 2008 7th World Congress on Intelligent Control and Automation, 8552-8556.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 6-9, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 6-9, February 2023
Copyright © 2023 EJOSAT
Research Article

Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications

Yunus Emre Kuşin [1*], Merih Palandoken [2]

[1*] *Izmir Katip Celebi* University, Faculty of *Engineering and Architecture*, Departmant of *Electrical and Electronics Engineering*, İzmir, Turkey, (ORCID: 0000-0002-5906-8793), yekusin@gmail.com

[2] *Izmir Katip Celebi* University, Faculty of *Engineering and Architecture*, Departmant of *Electrical and Electronics Engineering*, İzmir, Turkey, (ORCID: 0000-0003-3487-2467), merih.palandoken@ikc.edu.tr

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1252559)

ATIF/REFERENCE: Kuşin, Y. E. & Palandoken, M. (2023). Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications. *European Journal of Science and Technology*, (48), 6-9.

Abstract

In today's world, through the advancement of technology, wireless communication has become an integral part of our lives with the utilization of versatile electronic devices such as cell phones, tablets, and computers that contain wireless communication modules. The idea of utilizing different frequencies and power of RF signals in the environment has led to the concept of harvesting RF signals to produce DC output voltage. In this paper, a printed multiband monopole antenna is presented. The proposed antenna is composed of two Γ-shaped asymmetrically positioned feeding lines which are located on slotted truncated ground plane with three stubs loaded on both ground plane sides. The antenna design covers the frequently used frequencies for electronic device communication, such as GSM 1800, UMTS 2100, WLAN 2450 and LTE 2600 With the numerically computed gain values of 3.89dBi at 1.8GHz, 4.51dBi at 2.1GHz, 5.02dBi at 2.45GHz, and 5.03dBi at 2.6GHz, respectively. The proposed antenna design has permissible gain values to be used for RF energy harvesting applications.

Keywords: RF Energy Harvesting, Antenna Design, Monopole Antenna.

Γ-Shaped Asymmetrical Monopole Antenna on Truncated DGS For Multiband RF Energy Harvesting Applications

Öz

Günümüz dünyasında teknolojinin gelişimi ile birlikte cep telefonları, tabletler ve birgisayarlar gibi kablosuz iletişim modülü içeren cihazlar hayatımızın ayrılmaz bir parçası haline gelmiştir. Bu cihazlardan çevreye yayılan radyo frekans sinyallerinden DC çıkış voltajı üretme fikri RF enerji hasatlama fikrini ortaya çıkarmıştır. Bu bildiride baskılı multi-band monopol anten tasarımı sunulmaktadır. Antenin tasarımı asimetrik besleme hattına sahip, her iki yanı Γ şeklinde ve iç kısmında 3 yarıktan oluşmaktadır. Tasarlanan anten elektronik haberleşmede sıklıkla kullanılan GSM1800, UMTS 2100, WLAN 2450 ve LTE 2600 frekanslarını kapsar ve kazanç değerleri sırasıyla 1.8GHz'de 3.89dBi, 2.1GHz'de 4.51dBi, 2.45GHz'de 5.02dBi, 2.6GHz'de 5.03dBi değerlerinde sayısal olarak hesaplanmıştır.

Anahtar Kelimeler: RF Enerji Hasatlama, Anten Dizayn, Monopol Anten.

[*] Corresponding Author: yekusin@gmail.com

1. Introduction

Communication technology is developing with an exponential growth in today's world. Wireless electronic devices have become an undetachable part of our lives with development IoT technology. Especially daily used electronic devices are those that almost everyone has operated with the amount in billions today and they emit a certain amount of radio frequency energy[1]. Since radio frequency energy is transmitted to the receiver in omni-directions, most of the energy is wasted. For this reason, the idea of RF energy harvesting is introduced for the scavenging of wasted RF energy. The first RF power transmission system has been designed by Brown et. all. at NASA[2]. RF signals can carry energy with the power densities between 0.1μW/cm^2 and 0.01μW/cm^2[3].

Table 1. Performance of harvestable ambient energy sources with power density[3].

Energy Source	Types	Energy-Harvesting Method	Power Density
Radiant	Solar	Solar cells (indoors)	< 10μW/cm^2
		Solar cells (outdoors, sunny days)	15mW/cm^2
	Radio Frequency	Electromagnetic conversion	0.1μW/cm^2 (GSM)
		Electromagnetic conversion	0.01μW/cm^2 (WiFi)
Mechanical	Wind Flow and Hydro	Electromechanical conversion	16.2μW/cm^3
	Acoustic Noise	Piezoelectric	960nW/cm^3
	Motion	Piezoelectric	330μW/cm^3
Thermal	Body heat	Thermoelectric	40μW/cm^2

Compared to other energy sources, the energy content is very low. Therefore there is a requirement for an efficient system to harvest RF signals.

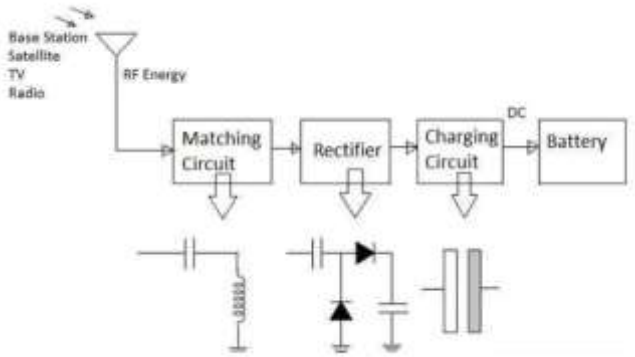


Fig. 1 RF energy harvesting system block diagram[4].

The typical block diagram of RF energy harvesting circuit is shown in Fig. 1 [4]. It consists of a receiving antenna, impedance matching circuit, rectifying circuit. The antenna receives radio frequency (RF) signals from the surrounding environment. To enable efficient and matched transmission of power between the antenna and rectifier circuit, a matching network is employed. The rectifier circuit converts the RF signal to direct current (DC) form. By utilizing a DC-DC converter, the desired voltage value can be achieved.

Recently, much progress has been made in RF energy harvesting technology[5]. Jeroen A.C. Theeuwes et.al are able to work the wall clock with the RF energy harvesting system which has been designed without cell battery[6]. Also, RF energy harvesting system has a very important place in the biomedical science. Wireless sensors implanted in the body are desired to be as small as possible and to be long-lasting.

Wireless sensors use batteries as an energy source for instance in the case of pacemakers. When these devices are implanted in the body, battery usage is undesirable because of it is bulky. In addition, the battery limits the operating times of the wireless sensors. Therefore, implanted sensors need to be replaced regularly, and this process requires surgical operation in the patient's body. Therefore, the patient may become infected[7]. If the wireless sensors used in the biomedical science work with the RF energy harvesting system, battery usage can be eliminated. In this way, patients are going to be able to live with this sensors for a lifetime without the need for surgical operation.

In this paper, multiband monopole antenna design used for RF energy harvesting system is presented. In Section II, the materials and methods used in antenna design are explained. In section III, the results of the designed antenna are shown. In Section IV, the discussion is conducted. In Section V, the study result is summarized.

2. Material and Method

In this study, a multiband monopole antenna is designed. Two Γ-shaped asymmetrically positioned feeding lines are located on slotted truncated ground plane with three stubs loaded on both sides of ground plane. The proposed antenna size is 60x90x0.87 mm^3 and has been optimized using parametric sweep. This antenna is printed on a RO4003C substrate with a dielectric constant of 3.55, loss tangent of 0.0027 and thickness of 0.87 mm. Annealed copper is used as ground and patch materials with 0.035 mm thickness.

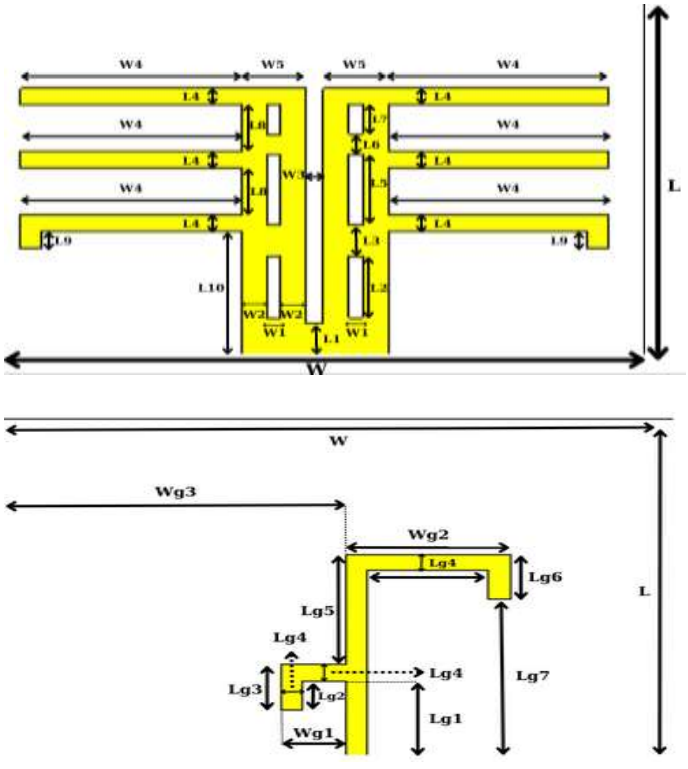


Fig. 2 Proposed antenna design.

Table 2. Parameters of the Proposed Antenna.

Par.	Value (mm)	Par.	Value (mm)	Par.	Value (mm)
W1	2	**L1**	5.5	**L6**	3.5
W2	3.425	**L2**	11.5	**L7**	5
W3	2.3	**L3**	5.5	**L8**	8.05
W4	30	**L4**	2.9	**L9**	3
W5	8.85	**L5**	12.4	**L10**	21.5
Wg1	8.65	**Wg2**	21.70	**Wg3**	43.85
Lg1	13.48	**Lg2**	5.15	**Lg3**	8
Lg4	2.85	**Lg5**	19.67	**Lg6**	8
Lg7	28	**W**	90	**L**	60

The designed antenna model is numerically computed.

3. Results and Discussion

3.1. Results

According to the simulation results, the bandwidths of antenna are 99.8 MHz (1496.5 MHz – 1596.3 MHz), 108.1 MHz (1701.4 MHz – 1809.5 MHz), 787.3 MHz (1828.8 MHz – 2616.1 MHz) respectively. The resonance frequencies are numerically computed as 1554 MHz (1496.5 MHz – 1596.3 MHz), 1803.4 MHz (1701.4 MHz – 1809.5 MHz), 1998.4 MHz and 2532 MHz (1828.8 MHz – 2616.1 MHz) respectively. Farfield parameters at 1.8 GHz, 2.1 GHz, 2.45 GHz and 2.6 GHz are summarized in Table 3. Also, 3D radiation patterns for 1.8 GHz, 2.1 GHz, 2.45 GHz, 2.6 GHz are given in Figure 4 and Figure 5, Figure 6, Figure 7.

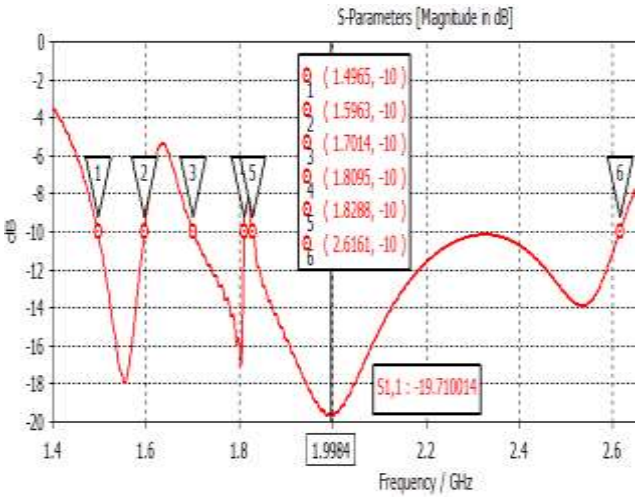


Fig. 3 S11 graph of proposed antenna.

The input reflection coefficients, S11 values of proposed antenna are -18 dB for 1554MHz, -16.995dB for 1803.4MHz, -19.7dB 1998.4 MHz, -13.9 dB for 2532 MHz.

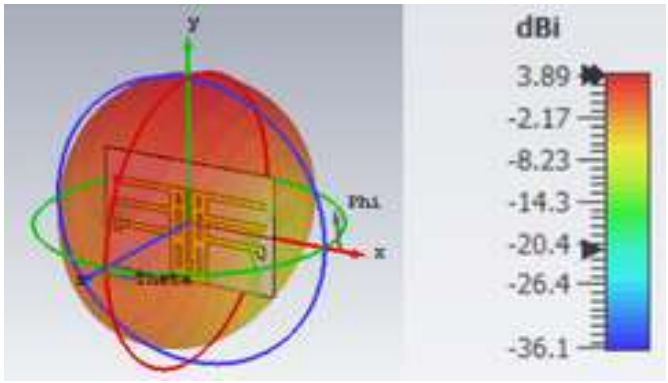


Fig. 4 Simulated 3D radiation pattern at 1.8 GHz for the proposed antenna.

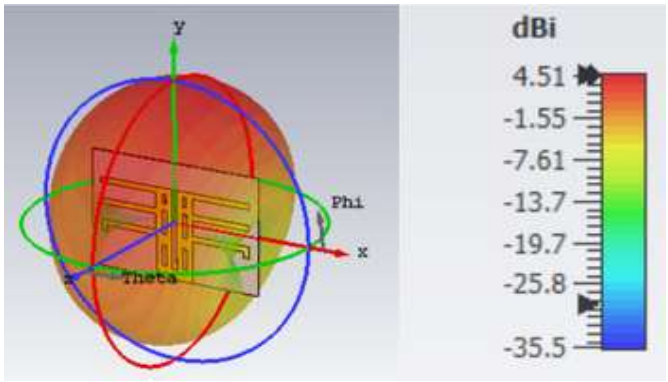


Fig. 5 Simulated 3D radiation pattern at 2.1 GHz for the proposed antenna.

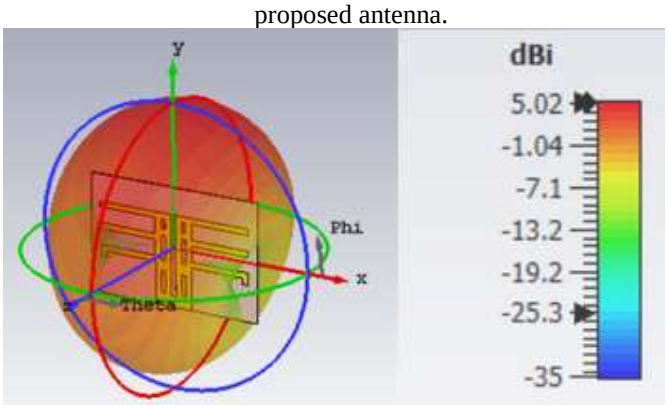


Fig. 6 Simulated 3D radiation pattern at 2.45 GHz for the proposed antenna.

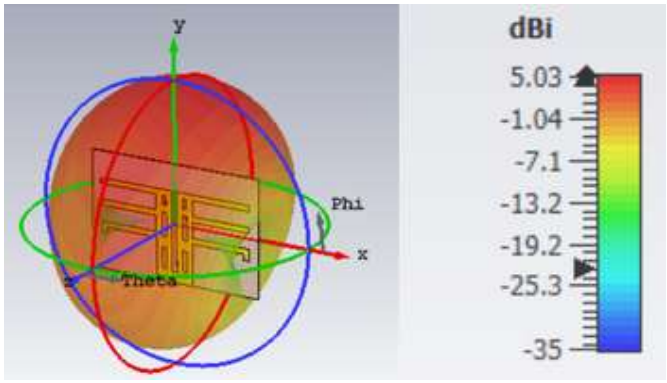


Fig. 7 Simulated 3D radiation pattern at 2.6 GHz for the proposed antenna.

Table 3. Gain, S11 and Efficiency values.

Frequency (GHz)	Gain (dBi)	S11 (dB)	Radiation Efficiency	Total Efficiency
1.8 GHz	3.89 dBi	-15.784 dB	%95	%92
2.1 GHz	4.51 dBi	-15.218 dB	%97	%94
2.45 GHz	5.02 dBi	-11.791 dB	%97	%90
2.6 GHz	5.03 dBi	-11.151 dB	%95	%88

3.2. Discussion

Many electronic devices operate where battery replacement is very costly, inconvenient or impossible. Therefore, there is a high demand for wireless energy transfer to these devices. There are two main advantages of using the RF energy harvesting system. First of all, unlike batteries, RF energy harvesting systems have an almost unlimited lifetime. Secondly, it is an environmental friendly as it does not create waste that pollute the environment. In consequence, the RF energy harvesting system is a very good alternative power supply for devices operating in extreme conditions.

4. Conclusions and Recommendations

In this paper, an antenna design that can harvest radio frequency energy at low power and high efficiency has been designed. The antenna can harvest the widely used in communication GSM 1800, UMTS 2100, WLAN 2450 and LTE 2600 frequencies. The gain values are 3.89dBi at 1.8GHz, 4.51dBi at 2.1GHz, 5.02dBi at 2.45GHz, and 5.03dBi at 2.6GHz, respectively. Based on these results, the antenna designed is proper for RF energy harvesting.

5. Acknowledge

This study has been carried out using the laboratory of Izmir Katip Celebi University Smart Factory Systems Application and Research Center (AFSUAM).

References

[1] Özkaya, U., & Seyfi, L. (2018). Dimension Forecast in Microstrip Antenna for C/X/Ku Band by Artificial Neural Network. *In 2nd International Symposium on Innovative Approaches in Scientific Studies* (Vol. 3, pp. 518-522).

[2] Brown, W. C. (1984). The history of power transmission by radio waves. *IEEE Transactions on microwave theory and techniques*, *32*(9), 1230-1242.

[3] Adu-Manu, K. S., Adam, N., Tapparello, C., Ayatollahi, H., & Heinzelman, W. (2018). Energy-harvesting wireless sensor networks (EH-WSNs) A review. *ACM Transactions on Sensor Networks (TOSN)*, *14*(2), 1-50.

[4] Shahabuddin, A. A., Shalu, P. D., & Akter, N. (2018). Optimized process design of rf energy harvesting circuit for low power devices. *International Journal of Applied Engineering Research*, *13*(2), 849-854.

[5] Takacs, A., Okba, A., Aubert, H., Charlot, S., & Calmon, P. F. (2017, May). Recent advances in electromagnetic energy harvesting and Wireless Power Transfer for IoT and SHM applications. In *2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and their Application to Mechatronics (ECMSM)* (pp. 1-4). IEEE.

[6] Theeuwes, J. A., Visser, H. J., Van Beurden, M. C., & Doodeman, G. J. (2007, October). Efficient, compact, wireless battery design. In *2007 European Conference on Wireless Technologies* (pp. 233-236). IEEE.

[7] Kim, Y. J., Bhamra, H. S., Joseph, J., & Irazoqui, P. P. (2015). An ultra-low-power RF energy-harvesting transceiver for multiple-node sensor application. *IEEE Transactions on Circuits and Systems II: Express Briefs*, *62*(11), 1028-1032.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 10-18, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 10-18, February 2023
Copyright © 2023 EJOSAT
Research Article

Thematic Park Congruence Analysis with Ecological Threshold Analysis Method, Case Study Çanakkale

Aylin Çelik Turan [1*], Murat Altınok[2]

[1*] Çanakkale 18 Mart University, Faculty of Architecture and Design, Departmant of Landscape Architecture, Çanakkale, Turkey, (ORCID: 0000-0002-1672-1254), aylin.celikturan@comu.edu.tr

[2] Çanakkale 18 Mart University, Faculty of Architecture and Design, Departmant of Landscape Architecture, Çanakkale, Turkey, (ORCID: 0000-0002-2985-9471), altinokmurat368@gmail.com

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1253939)

ATIF/REFERENCE: Çelik Turan, A., Altınok, M. (2023). Thematic Park Congruence Analysis with Ecological Threshold Analysis Method, Case Study Çanakkale. *European Journal of Science and Technology*, (48), 10-18.

Abstract

Thematic Parks are defined as open or closed spaces located in urban open green spaces, enabling people to live and work in a healthy way in urban life, reunification with nature, to get away from mental disorders and to do recreational activities. The most important difference of Thematic Parks from other recreational areas can be defined as the benefits they provide to the country's economy. Within the framework of planning criteria for Çanakkale-Center Thematic Park, which was chosen as the study area, a Thematic Park congruence analysis was carried out for Çanakkale with the Ecological Threshold Analysis Method using Geographic Information Systems (GIS). Land capability map, land use map, aspect map, slope map, elevation map, groundwater map and transportation map were created by classifying them in 1/25.000 scale from the maps to be used as a base in the analysis study. The maps used to determine the potential theme park area were divided into 1x1 km^2 grids and scored with a criterion value of 4 for each grid. As a result of the scoring, one each I. and II. degree potential area and three III. degree potential area has been determined. As a result, within the scope of this study, suitable site selection for a Thematic Park that can be applied in Çanakkale has been determined.

Keywords: Threshold Analysis, Thematic Park, Ecological Planning, GIS, Çanakkale

Çanakkale Örneğinde Ekolojik Eşik Analizi Yöntemiyle Tematik Park Uygunluk Analizi

Öz

Tematik Parklar, kentsel açık yeşil alanlar içerisinde yer alan, insanın kent hayatında sağlıklı yaşayabilmesini ve çalışabilmesini, bozulan bütünlüğüne yeniden erişebilmesini, ruhsal bozukluklardan uzaklaşıp rekreasyonel aktiviteler yapmasını sağlayan açık veya kapalı mekânlar olarak tanımlanmaktadırlar. Tematik Parkların diğer rekreatif alanlardan en önemli farkı ülke ekonomisine sağladığı yararlar olarak tanımlanabilir. Çalışma alanı olarak seçilen Çanakkale-Merkezin Tematik Parkı için planlama kıstasları çerçevesinde Coğrafi Bilgi Sistemleri (CBS) kullanılarak Ekolojik Eşik Analizi Yöntemiyle Çanakkale için Tematik Park uygunluk analizi yapılmıştır. Analiz çalışmasında kullanılacak arazi kabiliyet haritası, arazi kullanım haritası, bakı haritası, eğim haritası, yükseklik haritası, yeraltı suyu haritası ve ulaşım haritası ilgili kurumlardan alınan veriler doğrultusunda 1/25.000 ölçeğinde sınıflandırmaları yapılarak oluşturulmuştur. Potansiyel tematik park alanının belirlenmesi için kullanılan haritalar 1x1 km^2'lik gridlere bölünerek her bir grid için ölçüt değeri 4 üzerinden puanlandırılmıştır. Yapılan puanlama sonucunda birer tane I. ve II. derece potansiyel alan, üç tane III. derece potansiyel alan belirlenmiştir. Sonuç olarak bu çalışma kapsamında Çanakkale'de uygulanabilecek bir Tematik Park için uygun yer seçimi tespit edilmiştir.

Anahtar Kelimeler: Eşik Analizi, Tematik Park, Ekolojik Planlama, GIS, Çanakkale

[*] Corresponding Author: aylin.celikturan@comu.edu.tr

1. Introduction

The origin of thematic gardens dates back to medieval Europe and they were considered as gardens of happiness. There were functions such as fire games, playgrounds with toys, and trains (Gök and Bingöl, 2017). The widespread use of theme parks started in the 19th century in America was influenced by the industrial revolution. Founded in 1955, Disneyland pioneered the theme park to become an industry (Dalkılıç, 2007). Theme parks, which are the focus of attention all over the world, have become valuable areas in terms of tourism and the country's economy today (Gök and Bingöl, 2017).

Thematic parks are classified according to their size, diversity and sphere of influence. According to Braun, the classification of theme parks should be based on the characteristic and economic hierarchical order of the parks in the region (Braun, 2000). According to Gök and Bingöl, when thematic parks are evaluated in terms of their target audience, entertainment type and basic application points, they are divided into 5 basic classes (Gök and Bingöl, 2017).

1. Historical and cultural theme parks.
2. Education themed parks.
3. Story, fairy tale, mythology based parks.
4. Art themed parks.
5. Age themed parks.

Theme parks need special tourism planning and land use (Büyükşalvarcı and other, 2019). Investment services require multidisciplinary cooperation for services such as catering and entertainment. It should be planned within the framework of sustainable development in order to benefit from thematic parks and reduce their negative effects (Öztürk and Işınkaralar, 2019). Thematic parks can develop when planned according to three basic criteria (Gülhan, 2019). The first is to have a large land required for investment resources, the second is to have structural materials and special equipment, and the third is to have a planned business management.

It should also have three levels (national, regional and local) spatial planning as well as Tourism Planning, taking into account the risk factors (Kučinskienė, 2012).

Thematic park planning principles may differ according to its type and function. Considering user requests and satisfaction, the planning criteria should be as follows.

1- Feasibility reports should be taken into account in site selection.
2- It should be preferred that the park is on the main roads of the city in order to ensure accessibility in the selection of the location.
3- To integrate the historical, touristic and entertainment venues of the thematic park and to ensure sustainability by including it in the existing tourism route.
4- Determining usage needs and designing shopping areas for long-term use.
5- Consideration of natural, cultural, demographic, social and economic factors in order to increase the national and international tourist potential.
6- The defined spaces, activities and equipment should be open to development.
7- The curiosity of the users and the competitiveness between the functions should be increased (Deniz, 2002).

While planning and designing theme parks, a system open to everyone should be created (Uysal and Sun, 1994). Theme parks, which are built with a high investment cost, are organizations with high economic income, so they should have functions that will invite all visitors (İnce and Küçük, 2018).

Although Çanakkale has the potential of many theme parks with different themes, Aqualand is the only theme park with a water theme (Yanmaz, 2018). Çanakkale has a thematic park user potential in its internal dynamics (student potential presence, large number of retired people, presence of children and parents) (Özel, 2004). Its historical areas, natural potential and tourism destinations are important for the external dynamics of the city (Atalay and etc., 2019). The potential mass in both internal and external dynamics makes the formation of different thematic parks powerful: amusement park, health gardens, horticultural gardens etc. (Ertürk, 2017). In this study, potential Thematic Park suitable areas were determined in the city of Çanakkale by taking this potential mass as a driving force.

2. Material and Method

2.1. Material

The research area was chosen as the center of Çanakkale Province, which is located within the borders of the Marmara Region (Figure 1).

Figure 1. The location of the study (produced by the authors using Maphill, Google Earth and ArcGIS).

The main material of the research consists of the Land Use Capability (LUC) map and Major Soil Groups (MSG) map obtained from the Ministry of Agriculture and Forestry, the Çanakkale 1/5000 Master Plan obtained from the Çanakkale Municipality and documents obtained from Earthdata (earthdata, 2022). In the creation of Land Use Capability (Table 1), Large Soil Part and Land Use Maps, vector data in numerical shapefile (*.shp) format obtained from the Ministry of Agriculture and Forestry were used.

Table 1. Canakkale areal sizes (ha) of land use capability class by districts. (created by the authors)

LUC	Esenler District (ha)	Cevatpaşa District (ha)	İsmetpaşa District (ha)	Barbaros District (ha)	Boğazkent District (ha)	Hamidiye District (ha)	Cumhuriyet District (ha)
I. and II. degree	30	2	63	58	1	1	134
III. degree	68	-	-	41	4	140	19
IV. degree	-	9	-	54	9	25	-
V. degree	46	30	12	180	4	33	46
VI, VII and VIII degree	6	-	1	59	-	8	2
TOTAL	150	41	76	392	18	207	201

On the 1x1 km^2 grid system created within the scope of Kiemtedt's Method (Çelikyay, 2005), the base at the borders determined in the shapefile files was overlapped and maps were created by coloring on each area feature. Aspect, Slope and Relief

maps were created using 10x10 digital elevation model (DEM) data obtained from Eartdata. For this, "processing-clip" was performed by selecting our own area boundary over Image Analysis Tools via Geographical Information Systems (ArcGIS). Thus, after the DEM data was matured within the field boundary, the DEM data in raster format was converted into vector data. Aspect, Hillshade, Slope maps in ArcGIS (via 3D Analyst Tools-Raster Surface) are placed on a 1x1 km^2 grid system located on the WGS 1984 UTM Zone 35N coordinate system within the specified qualities. The scale of all maps created was determined as 1/25.000.

2.2. Method

For the Thematic Park, which will be examined in this study, the degree of congruence of ecological factors, that is, the potential value of ecological factors for use, has been determined. The following formula was used for the value analysis of the natural potential for sectoral uses (Çelikyay, 2005).

$$SAK_{PD}=Factor1_{PD}+ Factor2_{PD}+ Factor3_{PD}\ldots Factor(n)_{PD} \quad (2.1)$$

SAK=Sectoral Land Use (Sektörel Arazi Kullanımı)

PD= Potential value (Potansiyel Değer)

The potential value of an area for sectoral land use is the sum of the potential values of ecological factors in that land use.

$$SAK_{PD}=\Sigma PD=g_1.e_1.v_1+\ldots+ g_n.e_n.v_n \quad (2.2)$$

$$PD=_{g.e.v} \quad (2.3)$$

$SAK_{PD=}$ Potential value for land use.

PD= The potential value of the ecological factor in relation to land use.

g= The criterion weight rating.

e= Function value.

v= Priority value for land use.

This mathematical formula forms the basis of the "value analysis of natural potential for sectoral uses" method (Çelikyay, 2005).

3. Results and Discussion

3.1. Results

The maps prepared in the Geographic Information System (ArcGIS) and used as a base for the Thematic Park location selection of the city of Çanakkale are given the number value (1, 2, 3….18) to the rows and the letter value (A, B, C…..L) to the columns. As a result of this division, 31 grids of 1x1 km^2 were created (Fadel, 2016).

3.1.1. Use Land Capability

Points are given according to the proper of the area within the scope of the criteria determined in each grid. The lands on which irrigated farming is carried out on the area border are those that have I. class land use capability and have soil properties suitable for agricultural production. Sloping lands consisting of forest areas in the eastern and south-eastern parts of the research area, VI. and VII. are the lands that have the class of land use capability. Within the scope of these features determined for Land Use Capability, I-II-III in the grid. Class lands and VII-VIII. Class lands are given 1 point. For VI. class land was given 2 points, for IV. class land was given 3 points, and for V. class land was given 4 points (Figure 2).

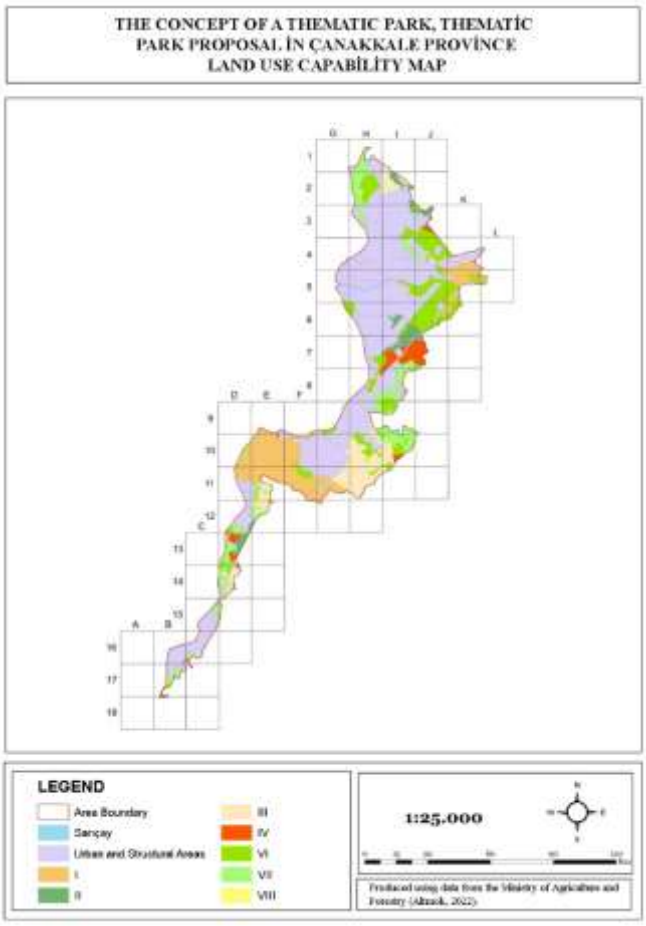


Figure 2. Canakkale-Central Land Use Capability Map

3.1.2. Land Use

The land uses in the research area, which includes the residential area and development areas of the Çanakkale central district, industrial zones, the coastal town of Kepez and the Dardanos coast along the coastline, as well as the village settlements, are shown in Figure 3. The agricultural lands in the study area are 140,138 ha, irrigated agriculture 48,853 ha, fallow dry agriculture 49,935 ha and a total of 237,926 ha agriculture is done in the area. Forest assets in the research area cover an area of 130,691 ha. In addition, the total area of heathland is 56,885

ha. The amount of areas under meadow-pasture use is 64,488 ha, which is quite insufficient.

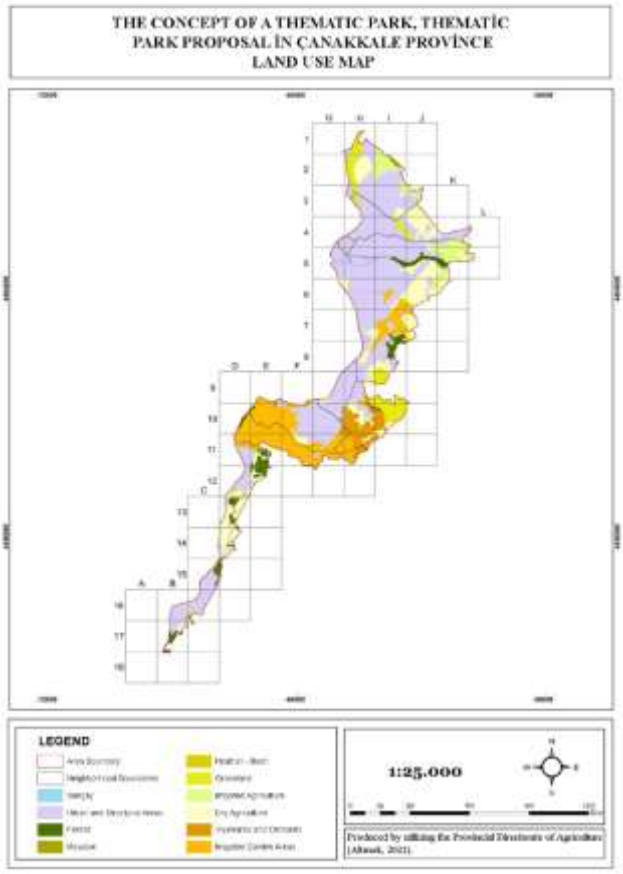


Figure 3. Canakkale-Center Land Use Map.

The points given for the use of land in the grid in the Land Use are as follows; 1 point for airport, military and natural sites, 2 points for residential areas and recreation, 3 points for higher education, 4 points for industry and trade. Destroyed areas were taken into consideration in the location selection of the thematic park. Thus, in the design dimension of the park, it was aimed to repair ecologically, increase the frequency of use and create livable environments.

3.1.3. Aspect

Since the "south, southeast, southwest and west" aspects are generally warmer in the geography of Turkey, these are called sunny aspects. On the contrary, since the "north, northeast, northwest and east" aspects are cooler, they are also called shaded aspects. The sunbathing times of these two groups are significantly different from each other (Çepel, 1988). The aspect of the research area is shown in Figure 4.

A high degree of score was given to the aspects of the idle area, where the wind is strong and in need of maintenance. The regions that receive the northeastern wind are important in terms of gaining the existing working area that may require maintenance in the area. Aspect directions with southerly winds received low scores. The South aspect received 1 point, the East-Southeast aspect received 2 points, the West-Southwest aspect received 3 points, and the North-Northwest aspect received 4 points.

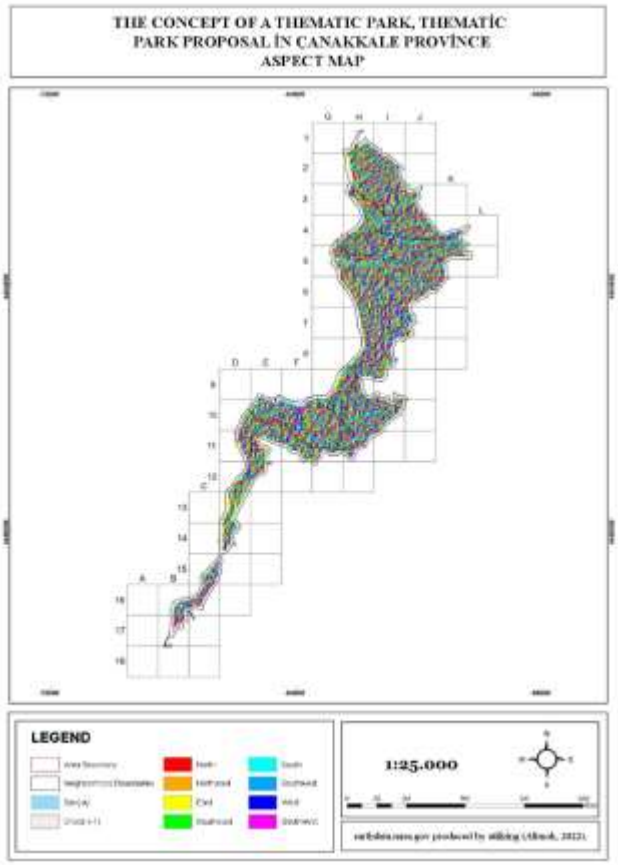


Figure 4. Çanakkale-Center aspect map.

3.1.4. Major Soil Groups

The needle leaves and vegetable wastes found on the soils of the Aegean Region decompose with the effect of heat and precipitation and mix with the soil. For this reason, there are alluvial soils in places with an altitude below 100 meter. However, as a result of low temperatures in high places, organic materials decompose late and remain on the soil for a long time (Şahin and etc.,2007). The major soil groups in the study area are seen on the map in Figure 5.

Scoring assessment of species among major soil groups is given based on permeability and ability to sustain existing vegetation. While making this scoring, factors such as landslide and erosion were also evaluated. Brown forest soils, red brown Mediterranean soils, limeless brown forest soils received the lowest score. Alluvial soils, colluvial soils and vertisols were given the highest scores.

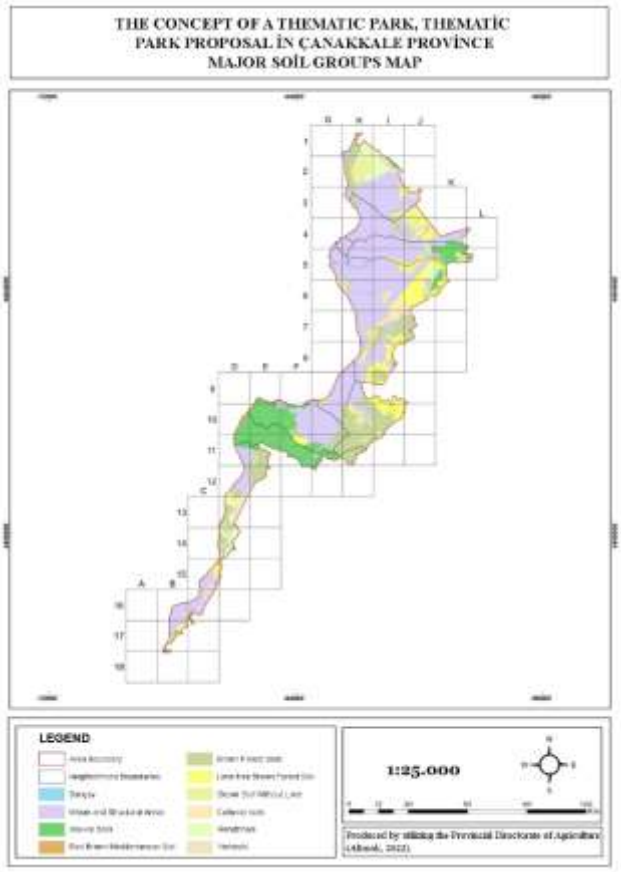


Figure 5. Çanakkale-Center major soil groups map.

3.1.5. Slope

The slope percentage of the areas around Sarı Stream and its tributaries in the research area is 0-2%. The slope percentage on the slopes of the irrigated farming areas, which are in the II and III class land capability class within the study area, is 2-6%, and the slope percentage in the other part is between 6-12%. In general, the study area consists of areas in the 4-7% slope group. We can classify the land cover in these areas as forest and dry agriculture. The slope map of the research area is shown in Figure 6.

According to the Thematic Park application criteria, the lowest value, 1 point, was given because the land slope is not suitable for flat and very rough areas. In addition, areas with a slope of 20-32% are known as lands unsuitable for the use of theme parks. As the degree of slope increases, the surface flow of precipitation waters also increases. In parallel with this, the severity of erosion increases and the soil depth decreases. Very sloping lands are unsuitable places in terms of nutrient and water economy. As a result, it is defined as arid and poor soils. Therefore, the highest value of 4 points is given to areas with a slope of 2-6%.

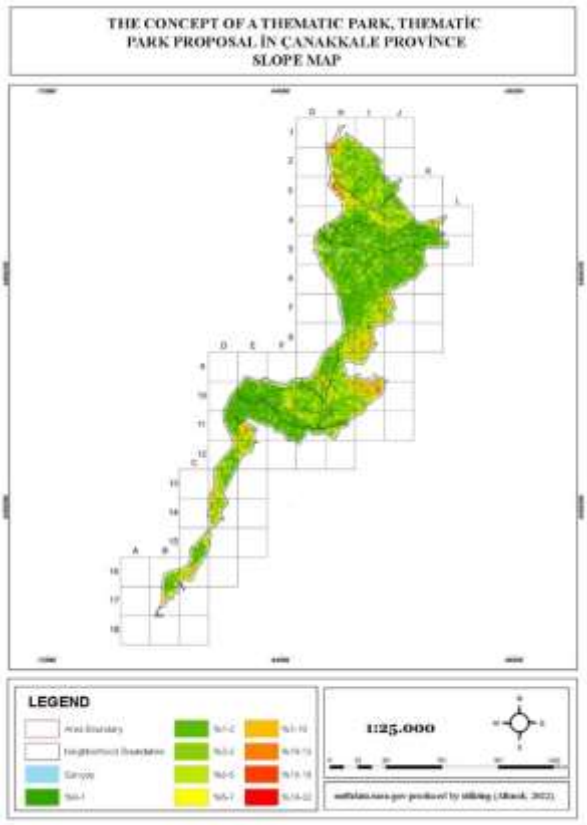


Figure 6. Çanakkale-Center slope map.

3.1.6. Elevation

The land around the Sarı Stream in the research area consists of sloping ridges and hills (Figure 7). While the settled area of Çanakkale Center is flat, the area where Esenler District and University Campus is located is surrounded by hills.

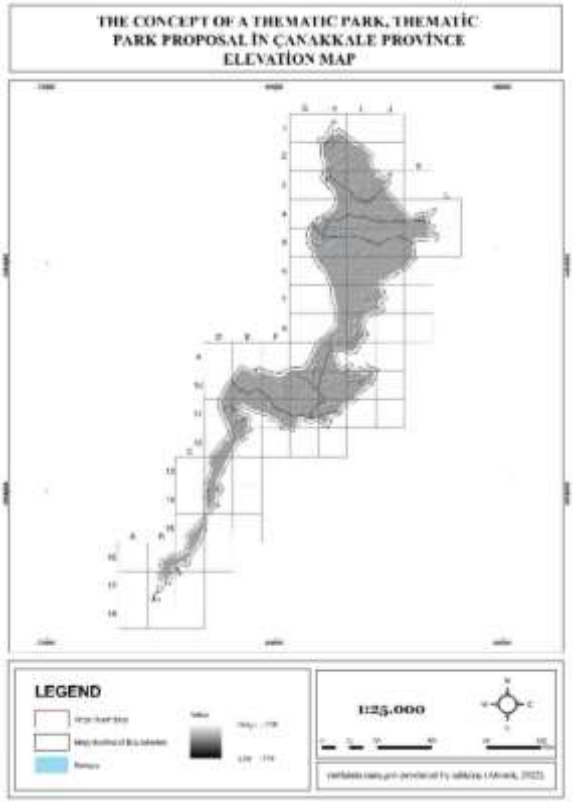


Figure 7. Çanakkale-Center elevation map.

3.1.7. Underground water

The research area, which has the temperate climate characteristics of the Aegean Region, generally receives precipitation in all seasons. Therefore, it is rich in surface and underground water resources (Figure 8). The most important stream of Çanakkale is Sarı Stream. Thanks to the sufficient water level of the Sarı Çay, which flows into the Dardanelles, ships of 500 tons can enter within 15 km of the city. With this feature, it is an important area of Turkey.

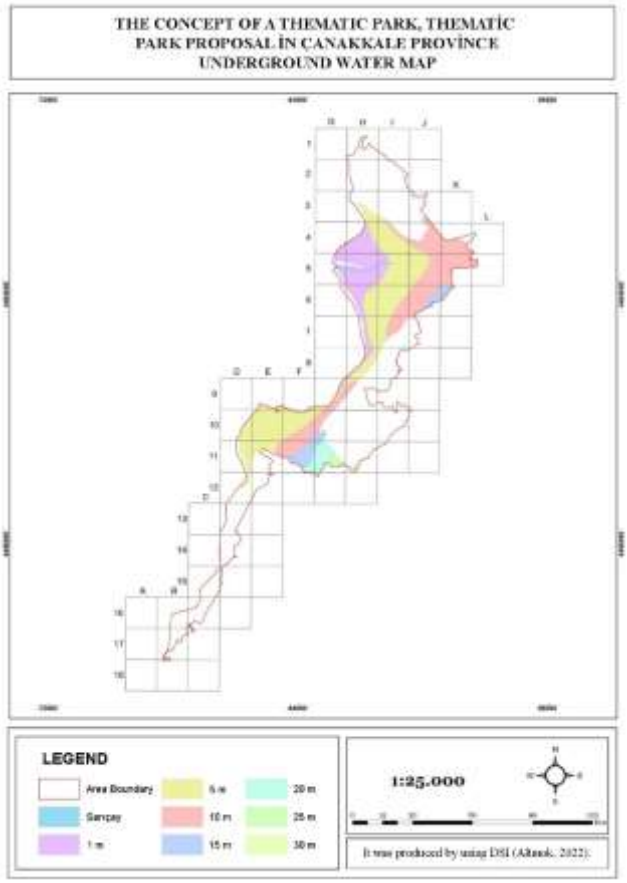


Figure 8. Çanakkale-Center underground water map.

3.1.8. Transportation

The main road of the city passes over lands where there is no or very little slope. Çanakkale is important in that it is located on the East-West, North-South corridor of global goods and services movement routes. Sea transportation on the study area also provides significant advantages in terms of logistics. The map of the existing transportation axes and the road grading in the research area is shown in Figure 9.

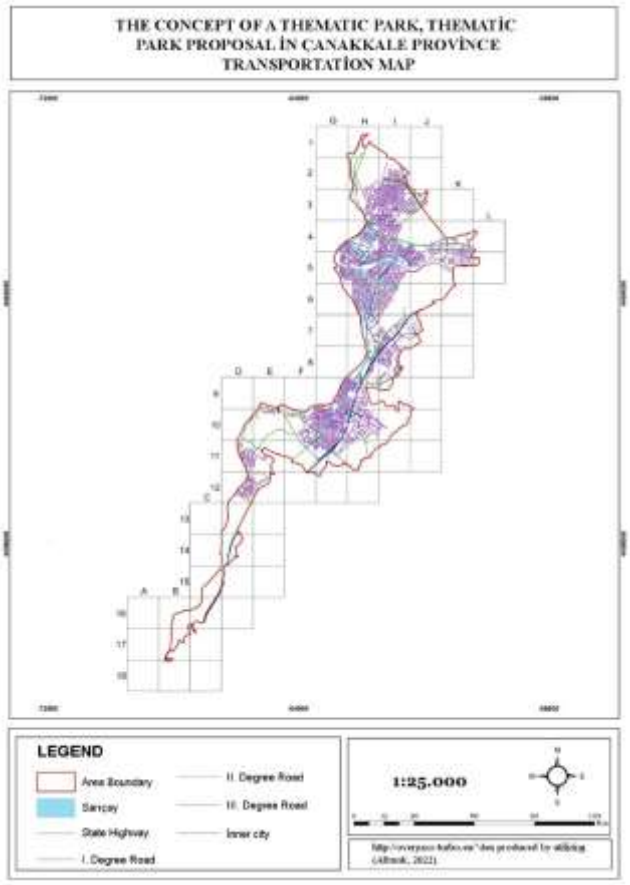


Figure 9. Çanakkale-Center transportation map.

3.1.8. Assessment of Natural Factor

The potential value was developed by determining the sub-factors that constitute the ecological threshold for the use of thematic parks and was formed by giving the function values. The main ones of these selected sub-factors are; land uses, major soil groups, slope, groundwater, aspect, land capability, road networks. Class of I., II. and III. lands are suitable for growing all kinds of plants growing in the region, the slopes are flat, well-drained, easily cultivated, deep and fertile. For this reason, lands with I., II. and III. land use capability classes were given 1 point because they were not suitable for thematic park use. 3 points are given to IV class lands that have very severe limiting features in terms of soil depth, stoniness, wetness and inclination and can only be cultivated with appropriate plowing for a few specific plant species. These areas have been given such high points because the areas that have been made ready for use again by repairing the destroyed and abandoned areas are suitable for thematic park. Since the flattest and roughest areas of the land slope are not suitable for thematic park, these areas are given 1 point. In areas where the slope is 20-32%, the surface flow of precipitation waters increases, erosion becomes severe and soil depth decreases. Therefore, these areas are defined as arid and poor places that are unfavorable in terms of nutrient and water economy. Therefore, areas with a 2-6% slope were given the highest value of 4 points. The ecological factors described above, the ecological sub-factors constituting the threshold for agricultural use, and their criterion weights and function values were produced by using Çelikyay (2005). The slope and land use capability criteria values are shown in Table 2.

Table 2. Natural factor evaluation table for areas with Thematic Park potential (Slope-LUC)

Criteria	Slope					Land Use Capability							
Criteria Weight	3					1							
Sub-Criteria	% 0-2	% 2-6	% 6-12	% 12-20	% 20-32	I	II	III	IV	V	VI	VII	VIII
Function Values	1	4	3	2	1	1	1	1	1	4	2	1	1
Potential Values of Metrics	$Slope_{PV}$					LUC_{PV}							
PV=TPV	THE POTENTİAL VALUE of THEMATİC PARKİNG												
Average TPV	Average Thematic PV=(Max. ThematicPV+MinThematic)/2= (12+3)/2=7,5												
Evaluation													
Result	Not available			II. Degree Potential					I. Degree Potential				

Source: Produced by using the data of the Ministry of Agriculture and Forestry.

When the land uses are examined, the lowest value of 1 is given to the areas where thematic parks cannot be built. Military Area, Airport and Natural Protected Area can be given as examples of land uses of this value. High points have been given to areas such as higher education, industrial zone and commercial area, which can be shown as examples of suitable areas in land use. The scores given in this section were evaluated according to the applicability of the fields, and the ecological sub-factors and their related criterion weights and function values are shown in Table 3.

Scoring criteria for species among major soil groups is given based on the presence of existing vegetation and base permeability. The criterion evaluation scores of large soil groups are shown in Table 3.

Table 3. Land use and natural factor evaluation table of large soil groups for areas with Thematic Park potential.

Criteria	Land Use							Major Soil Groups							
Criteria Weight	1							1							
Sub-Criteria	Forest	Meadow	Heather-Bush	Grassland	Irr. Agriculture	Dry Agriculture	Viyenards	Irr. Garden	Alluvial Soils	Red Bro. Med	Brown Forest	L. brow Bro. For	Bro. Wit. Li.	Colluvial	Rendzinals	Vertisols
Function Values	1	4	1	3	4	1	2	2	1	1	1	1	2	3	2	4
Potential Values of Metrics	LU_{PV}							MSG_{PV}							
PV=TPV	THE POTENTİAL VALUE of THEMATİC PARKİNG														
Average TPV	Average Thematic PV=(Max. ThematicPV+MinThematic)/2= (18+4)/2=10														
Evaluation															
Result	Not available				II. Degree Potential							I. Degree Potential			

Source: It was produced by using Çanakkale Construction Plan data.

In determining the potential values of the road masters, the areas far from the city but on the main road were evaluated as having high appropriate for thematic park. For this, high points were given to the state highway and first degree roads. Areas with structural densities in or near the city were given low scores. Evaluation scores related to transportation are shown in Table 4.

Aspect directions with strong winds and idle areas were given high scores. It is very important to acquire the regions that are under the influence of the northeast wind and the neglected areas in need of renewal. These areas are given high mark. Some aspects of southerly winds were given low scores. This situational assessment is clearly illustrated in Table 4.

Table 4. Aspect and transportation natural factor evaluation table for areas with Thematic Park potential.

Criteria	Transportation					Aspect								
Criteria Weight	1					1								
Sub-Criteria	State Highway	I. Degree Road	II. Degree Road	III. Degree Road	Inner City	North	Northeast	East	Southeast	South	Southwest	West	Northwest	North
Function Values	4	3	2	1	1	4	3	2	2	1	3	3	4	4
Potential Values of Metrics	TP_{PV}					$Aspect_{PV}$								
PV=TPV	THE POTENTİAL VALUE of THEMATİC PARKİNG													
Average TPV	Average Thematic PV=(Max. ThematicPV+MinThematic)/2= (16+4)/2=10													
Evaluation														
Result	Not available			II. Degree Potential					I. Degree Potential					

Source: Produced using earthdata.nasa.tr.

In the groundwater potential evaluation, high points were given to the waters at this depth since the depths where water access is easiest show that the most appropriate irrigation method will be in that region. The part that includes the evaluation criteria can be seen in Table 5.

Table 5. Groundwater natural factor evaluation table for areas with Thematic Park potential.

Criteria	Underground Water						
Criteria Weight	1						
Sub-Criteria	1 m	5 m	10 m	15 m	20 m	25 m	30 m
Function Values	4	3	2	1	1	1	1
Potential Values of Metrics	UW_{PV}						
PV=TPV	THE POTENTİAL VALUE of THEMATİC PARKİNG						
Average TPV	Average Thematic PV=(Max. ThematicPV+MinThematic)/2= (4+1)/2=2,5						
Evaluation							
Result	Not available		II. Degree Potential			I. Degree Potential	

Source: It was produced by using the data of the State Hydraulic Works.

3.2. Discussion

In the thematic park appropriate analysis, the scores obtained for each criterion of the grids divided into 1 km squares were written (Table 6). As a result of the sum of the written scores, the grids with the highest score were determined. For this purpose, the grids with the highest scores were marked on the map and appropriate areas were determined.

In determining the working method, research and evaluation of many sources, the analysis of the plan and design studies of the sample theme parks, the use of criteria were created and comparisons were made with the areas to be selected in Çanakkale.

The main theme of the method in the study was determined by the standards of the theme parks and the places where the need is highest in terms of economic development.

By evaluating the findings obtained as a result of the study, it was aimed to proceed to the design stage after the selection of the proposed venue.

Table 6. Grid values of natural factors related to areas with Thematic Park potential.

District	B16	B17	C15	C16	D10	D11	D12	D13	D14	E10	E11	E12
Underground	0	0	0	0	3	3	3	0	0	3	3	3
Major soil groups	0	0	0	0	1	1	0	1	2	3	3	1
Land use capability	0	1	0	0	1	1	0	1	1	1	1	1
Slope	4	3	3	3	1	1	4	3	3	1	1	3
Land use	0	0	0	0	0	0	0	0	0	1	0	0
Transportation	0	0	0	4	1	1	1	3	3	1	1	1
TOTAL	4	4	3	7	7	7	8	8	9	10	9	9
District	F10	F11	G5	G9	G10	G11	H1	H2	H3	H4	H5	H6
Underground	3	1	4	2	2	1	0	0	3	4	4	3
Major soil groups	0	3	0	0	0	3	2	3	0	0	0	0
Land use capability	1	1	0	0	0	1	1	3	0	0	0	0
Slope	3	1	3	2	4	3	3	4	3	1	1	2
Land use	1	4	1	1	1	1	0	1	2	2	1	1
Transportation	2	3	1	2	2	3	3	3	2	2	2	2
TOTAL	10	13	9	7	9	12	9	14	10	9	8	8

District	H7	H8	H9	H10	H11	I2	I3	I4	I5	I6	I7	I8
Underground	3	3	2	0	1	0	3	3	3	3	2	0
Major soil groups	0	0	0	1	1	2	0	0	0	0	1	1
Land use capability	0	0	0	1	1	1	0	0	0	1	3	1
Slope	1	4	3	4	4	2	4	3	3	2	3	3
Land use	0	2	1	1	1	2	1	2	1	1	3	2
Transportation	2	4	3	3	3	1	1	3	3	2	4	3
Aspect												
TOTAL	6	13	9	10	11	8	9	11	10	9	16	10

District	I10	J3	J4	J5	J6	K4	K5
Underground	0	2	2	2	2	2	2
Major soil groups	1	1	1	1	1	3	3
Land use capability	2	3	3	3	4	1	1
Slope	2	1	4	1	1	2	1
Land use	1	2	2	1	0	3	2
Transportation	1	1	1	2	3	1	1
Aspect							
TOTAL	7	10	13	10	11	12	10

As seen in Table 6, J4, H8, F11, H2, I7 grids stand out as a result of the scoring in the grids. Grids with low scores were named "low congruence places", places with a moderately high sum of values were called "moderate congruence places", and grids with the highest value totals were called "high congruence places".

H8, F11, J4 grids with close scores were re-evaluated according to other parameters. As a result of this evaluation, the appropriate place was determined as J4. Because although the J4 grid is far from the city, in terms of the development of the city and being on the main road, it is easy for the users who will come to the park to access the city and outside the city.

As a result of the grid score, H2, which was determined as "moderately congruence area" and I7, which was determined as "highly congruence area", were not recommended due to the difficulty of access.

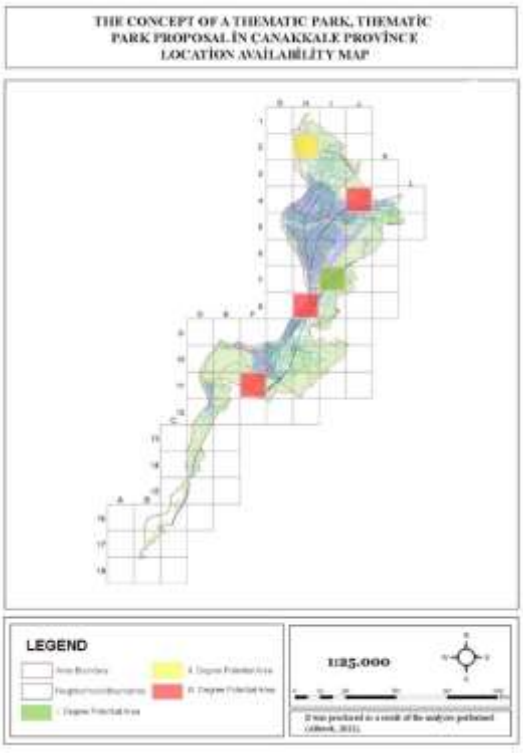


Figure 10. Thematic Park congruence map for Canakkale-Central

One of the important criteria for choosing the Thematic Park in the region called Tekzen is transportation, and it has been effective that an idle area provides ecological benefits with landscape restoration. Finally, in order to proceed to the design phase of the areas congruence for the Thematic Park determined as a result of the Threshold Analysis, the island, layout and parcels were examined (Figure 11).

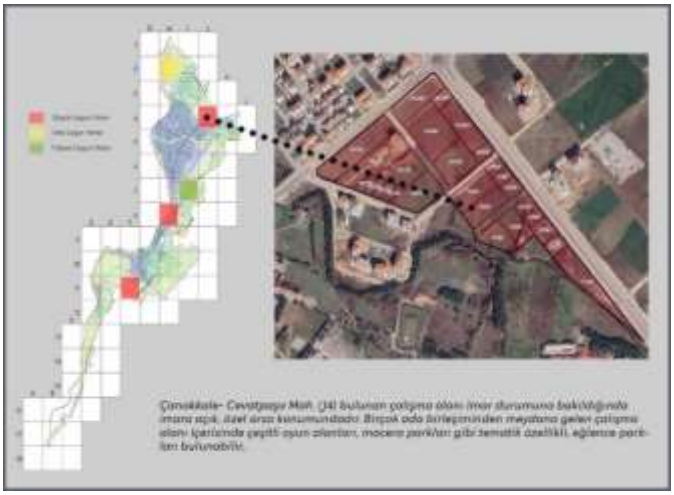


Figure 11. Study area of theme park.

4. Conclusions and Recommendations

In order to provide an ecological environment for living creatures, it is necessary to rehabilitate the destroyed areas and meet the needs of the places that need care. Many different concepts are being developed in landscape areas in order to create healthy and livable environments and at the same time to ensure the mental and physical tranquility of people. The theme that helps shape these concept ideas within the scope of a certain subject is the theme park (Figure 10).

Industrialization and migration wave cause population density in cities. Urban density causes deterioration of social balance and mental depression in cities. In addition, the development of social welfare in the city is in question with the presence of green areas.

Theme parks, which will meet this social need of people in line with the needs in the field, can help meet the recreational needs as well as their ecological contribution. From hobby gardens to amusement parks, from therapy gardens to sports fields, it can be mentioned that there are recreational green areas in many subjects.

Within the scope of this study, it is aimed to choose the appropriate place for the Thematic Park, which can be studied in Çanakkale, and to find the most suitable place with the Ecological Threshold Analysis method within the appropriate criteria grid system, which type of theme park can be built in this region.

Although there are many area assets and potential for thematic parks in Çanakkale, there are very few Thematic Parks. One of them is Aqualand, which has a water theme, and is the only thematic park in Çanakkale.

The potential presence of students, the large number of retired people, the presence of children and parents, and the fact that there is a rich audience that can create a theme for each generation, makes the concept of thematic park strong for Çanakkale.

Themes consisting of subjects such as an amusement park, health gardens, horticulture gardens that can meet the current potential of Çanakkale can be covered.

As a result, it is observed that the Thematic Park principle is actually a phenomenon that the city of Çanakkale needs. This shows us that the work done will be of high quality in all aspects if the situation is made in the most appropriate place, with the appropriate subject and place selection.

Suggestions; Considering the city of Çanakkale, there is a shortage of activities other than cafes, etc., which are mostly used by students. A stronger Çanakkale City Model will emerge with the amusement park work to be carried out on the selected area to prevent this shortage.

References

Atalay, L., Aksu, M., Yıldırım, H. and Korkmaz, H. (2019). Turizm Envanteri ve Strateji Çalışması-Çanakkale Destinasyonu. https://www.kalkinmakutuphanesi.gov.tr/assets/upload/dosyalar/canakkale-turizm-envanteri-strateji-calismasi.pdf

Braun, M. (2000). The Economic Impact of Theme Parks on Regions, NEURUS Paper.

Büyükşalvarcı, A., Aras, S., and Çınarlı, E. (2019), Turistik Ürün Çeşitlendirmesi Kapsaminda Tema Parklar, Konya Uluslararası Sosyal ve Beşeri Bilimler Araştırma Dergisi, s. 1198-1210.

Çelikyay, S. (2005). Arazi Kullanımlarının Ekolojik Eşik Analizi ile Belirlenmesi Bartın Örneğinde Bir Deneme, Yıldız Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Basılmamış Doktora Tezi, İstanbul.

Çepel, N. (1988). Peyzaj Ekolojisi Ders Kitabı, İstanbul Üniversitesi Orman Fakültesi Yayını, İstanbul.

Dalkılıç, E. (2007). Eğlence Parklarının Tarihsel Gelişimi ve Planlama Kriterleri, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

Deniz, G. (2002). Temalı Park ve Bahçelerin Planlama– Tasarım İlkeleri, Ankara Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

EarthExplorer, USGS science for a changing world, access date: 14.06.2022 https://earthexplorer.usgs.gov/

Ertürk, F. (2017). Çanakkale Kent Merkezinin Son 15 Yıldaki Kamusal Açık Yeşil Alan Değişimlerinin Kent Kimliği ve Kentsel Peyzaj Değişimi Üzerine Araştırmalar, Çanakkale Onsekiz Mart Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

Fadel, D. (2016). Valuation Methods of Landscape, International Journal of Research & Methodology in Social Science Vol. 2, No. 2, p.36, ISSN 2415-0371.

Gök, A. B. and Bingöl B. (2017). History and Cultural Themed Parks, Inonu University Journal of Art and Design, ISSN:1309-9876, Cilt/Vol. 7 Sayı/ No.12. 129-140.

Gülhan, M. (2019). Turizm Açısından Tema Parkların Ekonomik Etkileri: Sazova Parkı Örneği, Necmettin Erbakan Üniversitesi, Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, Konya.

İnce, S. and Küçük, K. (2018). Tematik Park Kavramı Kayseri Harikalar Diyarı Örneğinde İrdelenmesi, Journal of Architectural Sciences and Applications, 3 (1), 18-33, DOI: 10.30785/mbud.317796.

Kučinskienė, J. (2012). Entertainment Landscape Planning, Environmental Research, Engineering and Management, No. 1 (59), pg. 73-79.

Özel, E. (2004). Çanakkale İli Doğal ve Kültürel Potansiyelinin Turizm ve Rekreasyonel Kullanım Yönünden İncelenmesi, Çanakkale Onsekiz Mart Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, 2004.

Öztürk S., and Işınkaralar, Ö., (2019). Eğlence Parklarında Ziyaretçi Memnuniyet Düzeyinin Belirlenmesi: Wonderland Eurasia Tema Parkı Örneği, Sosyal Bilimler Enstitüsü Dergisi, s. 31-52.

Şahin, C., Doğanay H. and Özcan, N.A. (2007) *Türkiye Coğrafyası*, Gündüz Yayıncılık.

Uysal, M. and Sun, L. H. (1994). The Role of Theme Parks in Tourism, FIU, pg. 71-80.

Yanmaz, K. (2018). Tarihi Yapı ve Mekanlarda Mekansal Belleğin Korunması ve Kent Kimliğine Katkıları: Çanakkale Kentsel Sit Örneği, Çanakkale Onsekiz Mart Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 19-22, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 19-22, February 2023
Copyright © 2023 EJOSAT
Research Article

Mültecilere Yönelik Nefret Söyleminin Tespitinde Makine Öğrenmesi Modellerinin Kullanılması

Figen Eğin[1*], Vahide Bulut[2]

[1*] Katip Çelebi Üniversitesi,Mühendislik Fakültesi,Yazılım Mühendisliği, İzmir, Türkiye, (ORCID: 0000-0003-4865-5789), figenkayamail.com
2 Katip Çelebi Üniversitesi,Mühendislik Fakültesi,Yazılım Mühendisliği, İzmir, Türkiye, Türkiye (ORCID: 0000-0002-0786-8860),vahide.bulut@ikcu.edu.tr

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1253132)

ATIF/REFERENCE: Eğin, F. & Bulut, V. (2023). Mültecilere Yönelik Nefret Söyleminin Tespitinde Makine Öğrenmesi Modellerinin Kullanılması. *Avrupa Bilim ve Teknoloji Dergisi*, (48), 19-22.

Öz

Sosyal medya kullanımının yaygınlaşması ile birlikte sosyal ağlar üzerinden çeşitli gruplara yönelik nefret söylemi gibi olumsuz paylaşımların kontrolsüzce yayılabildiği görülmektedir. Suriye İç Savaşı'nı takiben Türkiye'ye yaşanan göç, mültecilere yönelik nefret söylemini gündeme getirmiştir. Nefret söylemi, toplumsal huzurun sağlanabilmesi için önüne geçilmesi gereken önemli bir hastalık olarak betimlenmektedir. Nefret söyleminin tespiti konusunda Türkçe dilinde yapılan çalışmaların ve nefret söyleminin tespitinde kullanılabilecek kapsamlı bir veri setinin eksikliği göz önüne alınarak bu araştırmada sosyal ağlarda Türkçe dilinde yapılan paylaşımlarda mültecilere yönelik nefret söyleminin makine öğrenmesi yöntemleri ile tespiti üzerine çalışılmıştır. Lojistik regresyon (LR), Yapay Sinir Ağı (YSA), Destek Vektör Makineleri (DVM), Karar Ağaçları ve Rastgele Orman modelleri uygulanarak deneysel sonuçlar karşılaştırmalı olarak sunulmuştur. Rastgele Orman, YSA ve LR ile elde edilen performans değerlerinin DVM ve Karar Ağaçları modellerinden daha yüksek olduğu ortaya konmuştur.

Anahtar Kelimeler: Nefret söylemi, mülteciler, makine öğrenmesi

Using Machine Learning Models to Detect Hate Speech Against Refugees

Abstract

With the widespread use of social media, it is seen that negative posts such as hate speech towards various groups can spread uncontrollably through social networks. The migration to Turkey following the Syrian Civil War has brought hate speech towards refugees to the agenda. Hate speech is described as an important disease that must be prevented in order to ensure social peace. Considering the lack of studies conducted in Turkish on the detection of hate speech and the lack of a comprehensive data set that can be used in the detection of hate speech, this research has been studied on the detection of hate speech against refugees using machine learning methods in Turkish language posts on social networks. Experimental results are presented comparatively by applying logistic regression (LR), Artificial Neural Network (ANN), Support Vector Machines (SVM), Decision Trees and Random Forest models. It has been revealed that the performance values obtained with Random Forest, ANN and LR are higher than the SVM and Decision Tree models.

Keywords: Hate speech, refugees, machine learning

[*] Sorumlu Yazar: figenkaya@gmail.com

1. Giriş

Sosyal medya, insanların kendilerini özgürce ifade edebilecekleri bir platform olarak betimlenmektedir. İnsanların hızlıca iletişim kurabildikleri ve daha büyük kitlelere seslerini duyurabildikleri bu platform büyük miktarlarda verinin çok hızlı bir şekilde paylaşılabilmesi nedeniyle toplumu belirli durumlara karşı kışkırtan söylemlere de ev sahipliği yapabilmektedir. Bu söylemlerin başında önüne geçilmesi gereken mühim bir sorun olarak betimlenen nefret söylemi gelmektedir [1]. Nefret söylemi, bir grup veya bireyi ırk, din veya cinsiyet gibi doğuştan gelen özelliklere dayalı olarak hedef alan ve toplumsal barışı tehdit edebilecek saldırgan söylemleri kapsamaktadır [2]. Suriye İç Savaşı nedeniyle 2011 yılından bu yana yoğun bir mülteci göçü ile karşı karşıya olan Türkiye'de, nefret söyleminin hedeflerinden biri de göçmenler olmuştur. Nefret söyleminin yaygınlaşmasının kolaylıkla nefret suçlarına yol açabileceği göz önüne alındığında toplumsal huzur ve barışın sağlanması için nefret söyleminin önüne geçilmesinin önemi ortaya çıkmaktadır [3].

Sosyal medya platformlarında nefret söyleminin önüne geçilmesinin, paylaşım miktarı ve hızının çok yüksek olması nedeniyle, insan gözetimiyle gerçekleştirilmesinin mümkün olmadığı görülmektedir. Bu noktada, otomatik bir şekilde tespit yapabilecek bir sisteminin gerekliliği ortaya çıkmaktadır [4]. Bu alanda yapılan çalışmaların son yıllarda artış gösterdiği ve çalışmalarda çok farklı yöntemlerin kullanıldığı görülmektedir. Nefret söyleminin metin madenciliği yöntemleriyle tespiti için kullanılan yöntemler incelendiğinde; makine öğrenmesi yöntemlerinin TF-IDF (%12), BERT (%12), CNN (%15), RNN (%17), leksikon tabanlı modeller (%15) ve hibrit algoritmalar (%29) olduğu; ayrıca makine öğrenmesi modelleri olarak destek vektör makineleri (DVM), Naive Bayes (NB), Lojistik Regresyon (LR), Karar Ağaçları ve K-En Yakın Komşu (KNN) algoritmalarının kullanıldığı ortaya konmuştur [5].

Nefret söyleminin tespitinde, özellikle metin tabanlı paylaşımların ağırlık kazandığı Twitter sosyal ağ hizmetinin gerekli verinin elde edilmesi için sıklıkla kullanıldığı görülmektedir. Twitter'dan çekilen verilerle yürütülen bir çalışmada Yunanca tweet'ler ile oluşturulan ve 1040 tanesi "toksik" ve 2964 tanesi "toksit değil" şeklinde etiketlenmiş 4004 tweet içeren bir veri seti kullanılmıştır. Yapılan bu çalışmada, mülteci ve sığınmacılara yönelik yabancı düşmanlığı, ırkçılık ve nefret söylemlerinin doğal dil işleme yöntemleri ile tespiti üzerine yoğunlaşılmıştır. BERT (Bidirectional Encoder Representations from Transformers) ve Resnet (Residual Neural Networks) algoritması uygulanmıştır. Model 0,97 doğruluk puanı ve 0,947 f1 puanı yakalamıştır. Yine Twitter'daki nefret ifadelerini tespit etmek için yürütülen başka bir çalışmada, eğitim setinden otomatik olarak toplanan unigramlara ve kalıplara dayanan bir yaklaşım önerilmiştir. Bu çalışmada bir tweet'in saldırgan olup olmadığı %87; bir tweet'in nefret dolu, saldırgan veya temiz olup olmadığını tespit etmede %78.4 doğruluk değerine ulaşılmıştır [6]. Djuric ve ark. [7] ise , nefret söyleminin tespitinde iki aşamalı bir model önermişlerdir. Öncelikle CBOW (Continous Bag of Words) NLP modelini kullandıkları çalışmalarında, yorumların ve kelimelerin ortak modellemesi için Paragraf2vec kullanmışlardır. En yüksek AUC değerine Paragraph2Vec ve LR algoritmasını birlikte kullandıkları model ile ulaşmışlardır.

Literatür incelendiğinde, Türkçe diline ilişkin veri seti ve yapılan çalışmaların ise yeterli olmadığı görülmektedir. Bu noktadan hareketle bu araştırmanın amacı, mültecilere yönelik Türkçe nefret söyleminin metin madenciliği yöntemleriyle tespitinin sağlanması olarak belirlenmiştir. Bu kapsamda öncelikle mültecilere yönelik nefret söylemi içeren Türkçe bir veri setinin oluşturulması, ardından bu veri seti kullanılarak çeşitli makine öğrenmesi modellerinin başarımlarının ortaya konması hedeflenmiştir.

2. Materyal ve Metot

2.1. Veri Setinin Oluşturulması

Bu çalışmada ilk olarak Türkçe dilinde mültecilere yönelik nefret söylemi veri seti oluşturulmuştur. Veri setinin oluşturulabilmesi için öncelikle verinin sağlanacağı sosyal medya ortamına karar verilmiştir. Özellikle metin şeklinde iletilerin paylaşıldığı ve yoğunlukla siyasi tartışmalar için kullanıldığı görülen Twitter araştırma kapsamında tercih edilmiştir. Tweet'lerin çekilmesi sürecinde sosyal ağ platformlarından veri çekmek için kullanılan SNScrape kullanılmıştır. SNScrape ile "mülteci, mülteciler, göçmen, göçmenler, ülkemdemülteciistemiyorum" anahtar kelimeleri kullanılarak gerçekleştirilen taramalar sonucunda, Twitter'dan 12200 tweet çekilmiştir. Sonrasında çekilen 12200 tweet incelenerek tekrarlayan ve alakasız olan tweet'ler veri setinden silinmiştir. Ardından kalan 10659 tweet'in, konuyla ilgili uzman 2 ayrı kodlayıcı tarafından "Nefret söylemi değil" (0) ve "Nefret Söylemi" (1) etiketleri ile etiketlenmesine geçilmiştir.

Nefret söyleminin tespit edilmesinde belirleyici öğelerin neler olacağına Papcunova ve ark. [8] tarafından yapılan çalışma temel alınarak karar verilmiştir. Bu çalışma kapsamında Papcunova ve ark. nefret söylemine yönelik kuramsal bir tanım ortaya koymak için birinde her yaş, cinsiyetten ve eğitim durumundan bireylerin diğerinde ise psikologların yer aldığı 2 odak grup oluşturmuşlardır. 2 ay boyunca yapılan 8 görüşmede göç ve mülteci konularına yoğunlaşılmıştır. Bu çalışma sonucunda, araştırmacılar nefret söylemini göçmenler bağlamında "şiddet içeren davranışları teşvik eden, insan haklarını reddeden, karalamalar, kaba sözler veya ad hominem saldırıları içeren, olumsuz klişeler kullanan, gerçeği veya tarihi gerçekleri kasıtlı olarak manipüle eden herhangi bir metin" olarak tanımlamışlardır. Etiketlemeler literatürdeki benzer çalışmalar da gözetilerek ve bu tanım temel alınarak yapılmıştır.

Kodlayıcılar tarafından etiketlenen veri setine ilişkin bir kesit Tablo.1'de sunulmuştur.

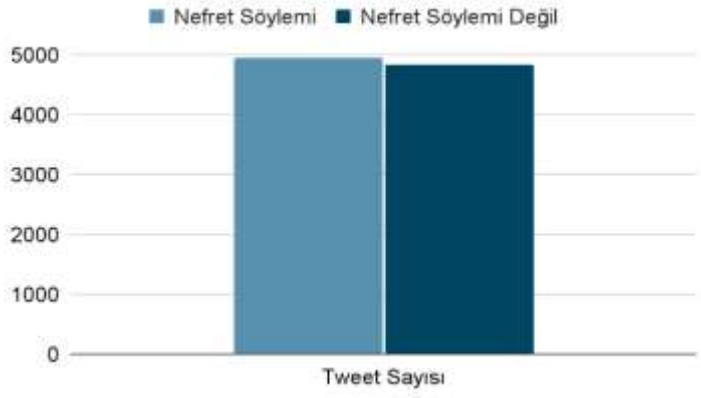
Verilerin etiketlenmesi tamamlandıktan sonra iki kodlayıcının 10659 tweet için %91,73 oranında benzer kodlama yaptığı görülmüşür. İki kodlayıcı arasındaki uyumun ölçülmesi için gerçekleştirilen Cohen's Kappa testi sonucunda Cohen's K değeri 0,835 ($p<0,01$) olarak hesaplanmıştır [9]. McHugh (2012)'a göre iki kodlamacı arasında "Güçlü düzeyde uyum" bulunduğu görülmüştür [10].

Tablo 1. Veri Setinden Bir Kesit

Tweet	Sınıf Etileti
Sığınmacılar, mülteciler adına ne denirse densin Türkiye için her zaman tehlikedir!	1
PKK nın 40 yılda veremediği zararı silahsız mülteciler verdi, kaç para harcadık belli değil.	1
İstanbul'da bayramda mülteciler için ücretsiz ulaşım imkanı tanınmayacak.	0
Avrupaya göç eden Türkler ile mülteciler aynı sebeple ülkelerini terk etmedi	0

Kodlayıcılar tarafından farklı etiketlenen 881 tweet silindikten sonra 4831 adet "Nefret söylemi değil" (NSD) ve 4947 adet "Nefret söylemi" (NS) etiketli toplam 9778 tweet içeren bir veri seti elde edilmiştir. Şekil 1'de yer alan veri setine ilişkin sınıf dağılımı incelendiğinde dengeli bir dağılım olduğu görülmektedir.

Şekil 1. Veri setinin sınıf dağılımı



2.2. Uygulanan Veri Ön İşleme Adımları

Verinin ön işlemesi, beş adımda tamamlanmıştır. Twitter üzerinden paylaşılan metinlerin birçok yazım hatası içerdiği, bazı tweet'lerde Türkçe karakterlerin kullanılmamasından kaynaklı yazım farklılıklarının olduğu görülmüştür. Öncelikle yazım hatalarının düzeltilmesi için Google Dökümanlar tarafından sunulan yazım denetimi servisi kullanılmıştır. Veri seti içerisindeki metinlerin tamamı küçük harfe çevrilerek fazla boşluklar, bağlantılar, karakterler, kullanıcı isimleri ve rakamlar silinmiştir. Metinler, sınıflandırmaya olumlu etkisi olmayan ve modelin başarımını düşüreceği tahmin edilen Türkçe dolgu kelimelerden arındırılmıştır. Son olarak metinde geçen kelimeler ek ve köklerine ayrılmıştır.

2.3. Kelime Temsil ve Sınıflandırma Yöntemleri

Bu çalışmada w2v kelime temsil yöntemi kullanılmıştır. Lojistik regresyon, Karar ağaçları, Destek Vektör Makineleri, Rastgele Orman ve Yapay Sinir Ağı makine öğrenmesi modelleri denenmiş, deneysel sonuçlar f1 ölçütü, kesinlik, geri çağırma ve doğruluk değerleriyle modellerin performansları değerlendirilmiştir. Tüm bu işlemler Python programlama dili kullanılarak gerçekleştirilmiştir.

3. Araştırma Sonuçları ve Tartışma

Veri seti üzerinde uygulanan modellerin performanslarının değerlendirilmesinde kullanılan ölçütler ve alınan sonuçlar Tablo 2'de sunulmuştur. Sonuçlar incelendiğinde doğruluk değerlerinin LR, YSA ve Rastgele Orman modellerinde eşit ve 0,68 olduğu; Karar Ağaçları modeli ile 0,65 doğruluk değerine ulaşıldığı ve en düşük doğruluk değerinin 0,65 ile DVM modeliyle elde edildiği görülmektedir (Tablo 3).

Nefret söyleminin tespiti halen üzerinde çalışılan bir doğal dil işleme problemi olarak karşımıza çıkmaktadır. Özellikle Türkçe dili üzerinde yapılan çalışmaların kısıtlılığı ve kapsamlı bir veri setinin eksikliği göze çarpmaktadır. Literatürdeki çalışmalar incelendiğinde 1000 adet veri ile gerçekleştirilen bir çalışmada, en yüksek performansın %79 f-ölçütü ile Sıralı Minimal Optimizasyon algoritması ile elde edildiği görülmüştür [4]. Başka bir çalışmada ise 40.623 tweet içeren ve sentetik olarak oluşturulmuş bir veri seti üzerinde Naive Bayes, Destek Vektör Makineleri, Karar Ağaçları ve Çok Katmanlı Algılayıcı modelleri uygulanmış ve en yüksek başarımın Karar Ağaçları ve Çok Katmanlı Algılayıcılar ile %80 olarak elde edildiği tespit edilmiştir [11]. DVM modelinin ve TF-IDF kelime temsil yönteminin nefret söyleminin tespitinde sıklıkla tercih edilen yöntemler olduğunu görülmektedir [12]. DVM modeli kullanılarak 14,509 tweet içeren bir veri seti ile yapılan çalışmada %78 doğruluk oranına ulaşılmıştır [13]. Bu çalışmada DVM ile elde edilen performansın diğer modellere göre daha düşük olmasının nedenlerinden birinin kullanılan kelime temsil yöntemi olabileceği düşünülmektedir.

Tablo 3. Uygulanan Modellere İlişkin Sonuçlar

Model	Sınıf Etiketi	Kesinlik	Duyarlılık	f1-ölçütü	Doğruluk
LR	0	0.65	0.81	0.72	0.68
	1	0.75	0.56	0.64	
Karar Ağaçları	0	0.66	0.65	0.65	0.65
	1	0.65	0.66	0.66	
DVM	0	0.59	0.95	0.72	0.64
	1	0.86	0.33	0.48	
Rastgele Orman	0	0.66	0.74	0.72	0.68
	1	0.75	0.56	0.64	
YSA	0	0.66	0.74	0.70	0.68
	1	0.71	0.62	0.66	

Bu çalışma ile literatüre en önemli katkının nefret söylemine yönelik kapsamlı bir Türkçe veri setinin oluşturulması olduğu düşünülmektedir.

4. Sonuç

Suriye İç Savaşını takiben Türkiye'ye Suriye'den yoğun bir göç yaşanmış ve yaşanan bu göç ile mültecilere yönelik olumsuz tepkilerin arttığı görülmüştür. Özellikle sosyal ağlar üzerinden yapılan yorumlarda nefret söyleminin engellenmesi, nefret suçlarının önlenmesi ve toplumsal huzurun korunması açısından önem taşımaktadır. Bu çalışmada nefret söyleminin Twitter sosyal ağı üzerinden Türkçe yapılan paylaşımlarda tespiti üzerinde çalışılmıştır. Öncelikle 9778 adet Türkçe tweet içeren ve "Nefret Söylemi" ve "Nefret Söylemi Değil" şeklinde etiketlenmiş bir veri seti oluşturulmuştur. Bu veri seti üzerinde uygulanan ön işleme adımlarından sonra W2V kelime temsil yaklaşımı kullanılarak çeşitli makine öğrenmesi modelleri uygulanmış ve sonuçlar kesinlik, doğruluk, f1-ölçütü duyarlılık ölçütleri temel alınarak karşılaştırılmıştır. Elde edilen sonuçlar incelendiğinde denenen 5 model içerisinde, Rastgele orman, YSA ve LR ile elde edilen doğruluk değerinin eşit ve DVM ve Karar Ağaçları modellerinden daha yüksek olduğu görülmektedir.

İleriki çalışmalarda veri seti üzerinde farklı kelime temsil yöntemleri, sınıflandırma algoritmaları ve derin öğrenme modelleri denenecektir

Kaynakça

1. Yanık, A. (2017). Sosyal medyada yükselen nefret söyleminin temelleri. *Global Media Journal TR Edition*, *8*(15), 364-383.
2. United Nations. (2022, Ağustos). Hate speech. Erişim Adresi: https://www.un.org/en/hate-speech/understanding-hate-speech/what-is-hate-speech
3. Aydos, S. S., ve Aydos, O. S. (2019). Yeni medyada nefret söylemi ve nefret söyleminden doğan hukukî sorumluluk. *Ankara Hacı Bayram Veli Üniversitesi Hukuk Fakültesi Dergisi*, *23*(2), 3-35.
4. Mayda, İ., Diri, B. ve Dalyan, T. (2021). Türkçe Tweetler üzerinde Makine Öğrenmesi ile Nefret Söylemi Tespiti. Avrupa Bilim ve Teknoloji Dergisi, (24), 328-334.
5. Ozkaya, U., Melgani, F., Bejiga, M. B., Seyfi, L., & Donelli, M. (2020). GPR B scan image analysis with deep learning methods. *Measurement*, *165*, 107770.
6. Watanabe, H., Bouazizi, M., & Ohtsuki, T. (2018). Hate speech on twitter: A pragmatic approach to collect hateful and offensive expressions and perform hate speech detection. *IEEE access*, *6*, 13825-13835.
7. Djuric, N., Zhou, J., Morris, R., Grbovic, M., Radosavljevic, V., Bhamidipati, N. (2015). Hate speech detection with comment embeddings, In Proceedings of the 24th international conference on world wide web, ss. 29-30
8. Papcunová, J., Martončik, M., Fedáková, D., Kentoš, M., Bozogáňová, M., Srba, I. & Adamkovič, M. (2021). Hate speech operationalization: a preliminary examination of hate speech indicators and their structure. *Complex & Intelligent Systems*, 1-16.
9. Cohen, J. (1960). A coefficient of agreement for nominal scales. Educational and Psychological Measurement, 20(1), 37-46.
10. McHugh, M. L. (2012). Interrater reliability: the kappa statistic. Biochemia Medica, 22(3), 276-282.
11. Baydoğan, V. C., ve Alatas, B. (2021). Çevrimiçi Sosyal Ağlarda Nefret Söylemi Tespiti için Yapay Zeka Temelli Algoritmaların Performans Değerlendirmesi. *Fırat Üniversitesi Mühendislik Bilimleri Dergisi*, *33*(2), 745-754.
12. Simon, H., Baha, B. Y., & Garba, E. J. (2022). Trends in machine learning on automatic detection of hate speech on social media platforms: A Systematic review. *FUW Trends in Science & Technology Journal*, *7*(1), 001-016.
13. Malmasi, S., & Zampieri, M. (2017). Detecting hate speech in social media. *arXiv preprint arXiv:1712.06427*.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 23-28, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 23-28, February 2023
Copyright © 2023 EJOSAT
Research Article

Random Forest Importance-Based Feature Ranking and Subset Selection for Slope Stability Assessment using the Ranger Implementation

Selçuk Demir[1*], Emrehan Kutluğ Şahin[2]

[1*] Bolu Abant Izzet Baysal University, Departmant of Civil Engineering, Bolu, Turkey, (ORCID: 0000-0003-2520-4395), selcukdemir@ibu.edu.tr
[2] Bolu Abant Izzet Baysal University, Departmant of Civil Engineering, Bolu, Turkey, (ORCID: 0000-0002-9830-8585), emrehansahin@ibu.edu.tr

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1254337)

ATIF/REFERENCE: Demir, S. & Sahin, E. (2023). Random Forest Importance-Based Feature Ranking and Subset Selection for Slope Stability Assessment using the Ranger Implementation. *European Journal of Science and Technology*, (48), 23-28.

Abstract

Stability problems of slopes can arise from various factors such as geometrical, geological, seismic etc. For many years, conventional methods such as limit equilibrium method, numerical methods, and statistical methods have been successfully utilized to predict the stability of slopes. On the other hand, several machine learning (ML) attempts have been made for predicting slope stability using datasets available in the literature. The present study aims to build classification models for the assessment of the stability of slopes using the Ranger algorithm. A total of 168 cases with six input parameters (slope height, unit weight, slope angle, cohesion, pore water pressure ratio, and internal friction angle) are used to generate models. In the first step, random forest (RF) feature importance scores of the six features are determined and five different prediction models were produced by reducing the feature numbers of the dataset. The developed models are then assessed using performance metrics and results are compared to choose the best prediction model. According to the obtained results, the feature importance-based feature ranking and subset selection approach (i.e., RF feature importance) affect the performance of the models. It is observed that from the RF feature importance scores, the unit weight is found to be the most influencing feature that affects the stability of slopes for the studied dataset. In addition, the Ranger model developed with five features (Model IV) achieves the highest test accuracy with a value of 90%.

Keywords: Feature Ranking, Machine Learning, Prediction Model, Ranger, Slope Stability

Ranger Uygulamasını Kullanarak Şev Stabilitesi Değerlendirmesi için Rastgele Orman Öneme Dayalı Öznitelik Sıralaması ve Alt Küme Seçimi

Öz

Şevlerin stabilite sorunları geometrik, jeolojik, sismik vb. çeşitli faktörlerden kaynaklanabilir. Şevlerin stabilitesini tahmin etmek için uzun yıllardır limit denge yöntemi, sayısal yöntemler ve istatistiksel yöntemler gibi geleneksel yöntemler başarıyla kullanılmıştır. Öte yandan, şev stabilitesini tahmin etmek için literatürde bulunan veri setlerini kullanılarak pek çok makine öğrenimi (ML) girişiminde de bulunulmuştur. Bu çalışma, Ranger algoritmasını kullanarak şev stabilitesinin değerlendirilmesi için sınıflandırma modelleri oluşturmayı amaçlamaktadır. Model oluşturmak için altı girdi parametresi bulunan (eğim yüksekliği, birim hacim ağırlık, eğim açısı, kohezyon, boşluk suyu basıncı oranı ve iç sürtünme açısı) toplamda 168 şev vakasından oluşan bir veri seti kullanılmıştır. İlk adımda, altı özelliğin rastgele orman (RF) öznitelik önem dereceleri belirlenmiş ve veri setinin değişken sayıları azaltılarak beş farklı tahmin modeli üretilmiştir. Geliştirilen modeller daha sonra performans metrikleri kullanılarak değerlendirilerek ve en iyi tahmin modelini seçmek için sonuçlar karşılaştırılmıştır. Elde edilen bulgulara göre, öznitelik önemine dayalı değişken sıralaması ve alt küme seçimi yaklaşımı (yani RF öznitelik önem derecesi) modellerin performansını etkilediği görülmüştür. RF öznitelik önem puanlarından, çalışılan veri seti için şev stabilitesini en çok etkileyen değişkenin birim hacim ağırlık olduğu görülmüştür. Ayrıca beş değişken ile geliştirilen Ranger modeli (Model IV) %90 değeri ile en yüksek test doğruluğuna ulaşmıştır.

Anahtar Kelimeler: Öznitelik Sıralaması, Makine Öğrenimi, Tahmin Modeli, Ranger, Şev Stabilitesi

[*] Corresponding Author: selcukdemir@ibu.edu.tr

1. Introduction

Slope stability is a critical topic of geotechnical engineering that plays a vital role in ensuring the safe and stable use of land for various purposes, such as infrastructure, residential, and industrial development. The term refers to the ability of a soil or rock slope to resist failure or collapse, which can have catastrophic consequences in areas prone to natural disasters such as earthquakes and landslides. As it affects the safety of people, property, and the environment, the assessment and prediction of slope stability are therefore essential in preventing and mitigating the risk of slope failures. The results of these assessments are used to identify potential problems and make recommendations for remedial measures to improve the stability of the slope.

There have been numerous methods for the evaluation and prediction of slope stability. Existing literature studies have already reported the use of evaluation methods, including limit equilibrium method (LEM), the characteristic line method, the limit analysis method, and the numerical modeling (Yang and Yin, 2004). LEM is one of the widely preferred methods for the assessment of slope stability due to its simplicity in application and analysis methodology (Lim et al., 2016; Jellali and Frikha, 2017; Cala and Flisiak, 2020). However, LEM inherently has some limitations despite being widely applied in practice. Also, LEM is not reliable where nonhomogeneous and anisotropic stratifications exist which generally include geotechnical uncertainties (Krahn, 2003; Xiao et al., 2018; Wang et al., 2020). Other studies have focused on developing sophisticated numerical models and methods for predicting slope failures, considering the complex and dynamic nature of soil and rock slopes. These mentioned models incorporate factors such as soil strength, groundwater conditions, and seismic activity, providing a more comprehensive picture of slope stability. Additionally, these are also useful for identifying the most critical failure modes and developing effective remedial measures to prevent slope failure. Briefly, numerical approaches provide valuable information about the slope's behavior over time, allowing engineers to develop more accurate predictions about its stability.

One of the recent advancements in the area of slope stability is the application of machine learning (ML) algorithms for evaluation and prediction. ML algorithms have been increasingly used for the analysis of large data sets and the prediction of various geotechnical parameters, including slope stability. These algorithms are capable of recognizing patterns and relationships in data and can be trained to make predictions based on this information (Alpaydin, 2020). Several studies have reported the potential of ML applications for evaluating the stability of slopes. For example, Samui (2008) evaluated the applicability of a support vector machine (SVM) for predicting the stability of slopes. Choobbasti et al. (2009) considered artificial neural network (ANN) for the prediction of slope stability in a specified location based on multilayer perceptron networks (MLP). Another study by Liu et al. (2014) used extreme learning machine (ELM) to investigate and evaluate the prediction of the stability of slopes. Abdalla et al. (2015) employed an MLP-ANN model to forecast the minimum factor of safety of slopes under static load for different data sets. Hoang and Pham (2016) evaluated historical earth slope cases using firefly algorithm (FA) and the least squares support vector machine (LSSVM). Chakraborty and Goswami (2017) investigated the prediction of slope stability using the ANN model. Hoang and Bui (2017) applied ELM, radial basis function neural network (RBFANN), and LSSVM algorithms to conduct a comparative study for slope stability assessment. Moayedi et al. (2019) examined the applicability and proficiency of various ML models in predicting slope stability. Pham et al. (2021) built ensemble-based stability prediction models based on 153 slope cases documented in published literature. Kardani et al. (2021) proposed artificial bee colony-optimized ML models based on a hybrid stacking ensemble approach to predict the stability of slopes. More recently, Lin et al. (2022) trained different ensemble learning approaches to build classification models for 444 slope cases and analyzed the prediction efficiency of the models. Wang et al. (2023) built different ML models using classical algorithms combined with dimension reduction methods for slope stability. Yang et al. (2023) performed a comparative analysis for slope stability using different ML algorithms by employing intelligent algorithm optimization. The studies highlight the potential of these techniques in providing accurate predictions of slope stability and showcase their effectiveness in the field of geotechnical engineering. In conclusion, ML algorithms are a promising tool for the prediction and evaluation of slope stability. However, future studies are needed to further explore the potential of ML algorithms in the field of slope stability and to evaluate their performance under different conditions. To this end, in this study, a feature ranking and a subset selection methodology using the RF feature importance were employed to generate prediction models. In general, feature ranking refers to the ordering of original features for a specific evaluation criterion, which is usually a step of feature selection. It is employed to determine which features are more important (Liu et al., 2022). A total of five different prediction models (i.e., Model I, II, III, IV, and V) were created based on the importance scores of the six features of the studied dataset for reducing the number of features.

The overall objective of this paper is to propose a slope stability prediction model by using RANdom forest GEneRator (Ranger), which is one of the implementations of the random forest (RF) algorithm. Hence, The Ranger implementation was used at the model prediction stage for each feature ranking and different models were produced for each ranking result. In this present study, in order to learn the best performance of the model, prediction models were evaluated through performance metrics (Accuracy, Recall, Precision, and F1-Score) and results were compared to demonstrate the best model that produced higher prediction performance.

2. Material and Method

2.1. Dataset Information

In this research, the dataset based on published literature (Sah et al., 1994, Lu and Rosenbaum, 2003, Zhou and Chen, 2009; Li and Wang, 2010, Xiaoming and Xibing, 2011) is used to create ML models. The dataset contains several field case histories obtained from different sites. A list of the slope cases can be found in Hoang and Pham (2016). The whole dataset comprises 168 slope cases, including 84 “stable” *(Yes)* and 84 “unstable” *(No)* slope cases. The features of the dataset are unit weight (γ), slope height (H), slope angle (β), cohesion (c), pore water pressure ratio (r_u), and angle of internal friction (ϕ). H is the vertical distance between the slope crest and the slope base. β is the angle that is computed based on the inclined plane and the base plane. γ refers to the weight of a unit volume of soil. it is determined by

the weight of the soil and the volume of the soil sample. c is one of the main shear strength parameters of soils or rocks with regard to the well-known Mohr-Coulomb failure criterion. ϕ is another soil or rock strength parameter that indicates its ability to withstand shear stresses. r_u is computed by dividing the pore water pressure by the overburden pressure. It should be noted that the r_u value in the last case (168th case given by Hoang and Pahm, 2016) is considered to be 0.45 since the minimum and maximum values of r_u should range between 0 and 1.0. Table 1 summarizes the information of the statistical descriptions of the features. Moreover, Fig. 1 shows the Pearson correlation matrix among six input features to clearly demonstrate the pairwise relationship between input features with the corresponding correlation coefficients. For this dataset, the correlation coefficient ranges between minimum -0.14 and maximum 0.63; thus, it can be concluded that there are no noteworthy correlations between each feature.

Table 1. Descriptive statistics

Features	Ave.	St.Dev.	Min.	Med.	Max.
γ	21.8	4.1	12.0	21.0	31.3
c	34.1	46.0	0.0	20.0	300.0
ϕ	28.7	10.6	0.0	30.2	45.0
β	36.1	10.2	16.0	35.0	59.0
H	104.2	133.1	3.6	50.0	511.0
r_u	0.2	0.2	0.0	0.3	0.5

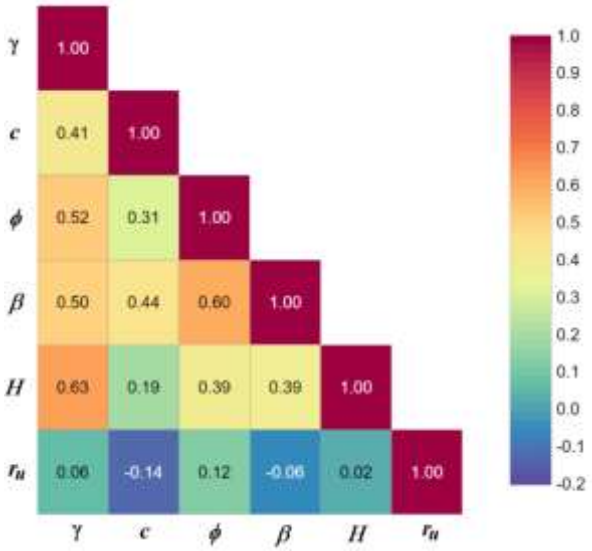


Figure 1. Illustration of the Pearson correlation plot

2.2. Feature Importance (FI) Analysis

This section presents FI analysis to examine the role of each influence variable in slope stability analysis. FI analysis is an essential process that can be considered in model interpretability and feature selection in ML. It is used to determine the most significant features or variables that contribute to the target variable. In other words, it helps to determine which variables have the most significant impact on the outcome of the model. In this study, the RF algorithm is applied to the train dataset to show the influencing features for slope stability analysis. The feature importance of all the six input features and their arrangement from top to bottom is given in Fig. 2. It can be seen that the unit weight (γ) is the most important feature influencing slope stability for this dataset. This means that the unit weight plays a key role in the evaluation of slope stability for the studied dataset. Moreover, cohesion (c) is the second most important feature among the other four features, followed by H, ϕ, β, and r_u. It is also worth mentioning that different FI scores may be obtained when different ML algorithms and datasets are employed (Guyon et al., 2008).

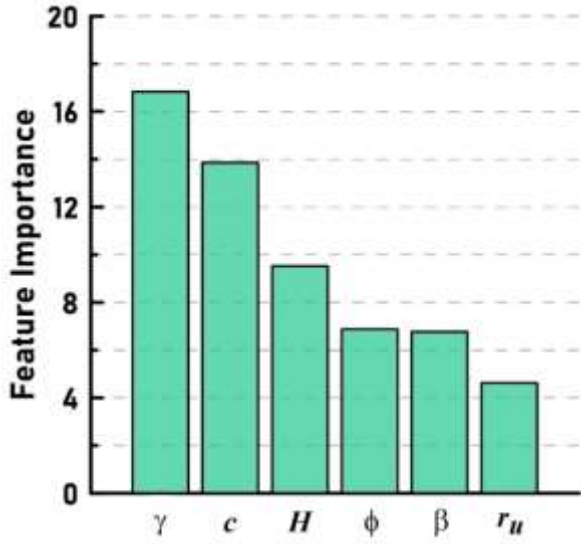


Figure 2. FI variation of the influencing features

2.3. RANdom forest GEneRator (Ranger)

Ranger, nearly equivalent to random forest (RF), is a fast implementation of the RF model. It supports classification, regression, survival and probability trees (Wright and Ziegler, 2015). Ranger is designed to be fast and memory-efficient, and it also uses a number of optimizations and parallel processing techniques to achieve this. For instance, Ranger is parallelizable, which allows it to take advantage of multiple processors to build the trees more quickly (Tiyasha et al., 2021). It applies a modified version of the binary search algorithm to quickly find the best split points for each feature, which reduces the computation time compared to other implementations of random forests (Hobeichi et al., 2022). Ranger is designed to use as little memory as possible, which makes it suitable for high-dimensional datasets that cannot fit in memory (Moon et al., 2022). The prediction error is obtained from the out-of-bag (OOB) samples. This eliminates the need for a separate validation set, which can save time and reduce the risk of overfitting.

2.4. Building ML Models

The slope dataset was divided into the training (70%) and test datasets (30%) using simple random sampling (Demir and Sahin, 2022) for model production and performance analysis. The training set was utilized for building ML models, whereas the test set was used for performance evaluation. In this study, five different prediction models were created including 2 to 6 features with respect to the ordered FI scores given in Fig. 2. Feature selection was conducted manually based on the FI scores and model performances were assessed considering the selected features to investigate the performance result of the models with various features. Table 2 presents the five prediction models with variable features. After the model structures were built, the Ranger algorithm was applied to predict slope stability and the performance measurements of the models were obtained with regard to four performance metrics to select the best model.

Table 2. Considered ML models with various features

	Prediction Models				
	Model I	Model II	Model III	Model IV	Model V
Features	γ	γ	γ	γ	γ
	c	c	c	c	c
		H	H	H	H
			ϕ	ϕ	ϕ
				β	β
					r_u

2.5. Building ML Models

The "*Ranger*" package in R software was applied in the study. Repeated 10-fold cross-validation (three times) and grid search was employed for tuning and determining the optimal hyperparameters of each model. Some hyperparameters of the Ranger algorithm (i.e., *mtry*, *ntree*) that should be tuned before model generation are given in Table 3. While *'mtry'* refers the number of variables available for splitting at each tree node, *'ntree'* represents the number of trees to grow. For all models, *'ntree'* and *'min.node.size'* were held constant at a value of 500 and 1.0, respectively. The final values of the hyperparameters used for the models are provided in Table 3.

Table 3. List of optimal hyperparameters of the models

Models	Features	Parameters	Best Value
Model I	γ, c	*mtry*	*2*
		ntree	*500*
		splitrule	*extratrees*
		min.node.size	*1*
Model II	γ, c, H	*mtry*	*3*
		ntree	*500*
		splitrule	*gini*
		min.node.size	*1*
Model III	γ, c, H, ϕ	*mtry*	4
		ntree	*500*
		splitrule	*gini*
		min.node.size	*1*
Model IV	γ, c, H, ϕ, β	*mtry*	5
		ntree	*500*
		splitrule	*gini*
		min.node.size	*1*
Model V	γ, c, H, ϕ, β , r_u	*mtry*	4
		ntree	*500*
		splitrule	*extratrees*
		min.node.size	*1*

2.6. Performance Measurements

The performance of the prediction models is evaluated using four metrics based on the confusion matrix (CM), namely Accuracy (*Acc*), Precision (*P*), Recall (*R*), and F1-Score (*F1*). CM is a specific table that allows visualization of counts correctly and incorrectly predicted by the model. The stable cases were regarded as positive class samples and the unstable cases as negative class ones. All metrics used for performance measurement take values in the range of 0 and 1. The details of the metrics are provided in Table 4.

Table 4. Performance evaluation metrics

		Reference: Yes	Reference: No	
Predicted	Yes	TP	FP	TP: True Positive FP: False Positive
	No	FN	TN	TN: True Negative FN: False Negative

Metrics	
Accuracy (Acc):	TP + TN/ (TP+TN+FP+FN)
Precision (P):	TP/ (TP+FP)
Recall (R):	TP/(TP+FN)
F1-Score (F1):	$(2xPxR)/(P+R)$

3. Results

The experimental results are depicted in Fig. 3. For comparison, different evaluation metrics discussed in Section F were used to thoroughly display prediction results. It was observed the following outcomes from Fig. 3: (i) Accuracy represents the ratio of the number of correctly predicted samples to the total samples. It is clearly seen that different feature subsets have an impact on the model test accuracies. *Acc* increases as the feature number increases up to five features. At this point, the highest *Acc* value is achieved with the value of 90% for Model IV. Thereafter, *Acc* decreased from Acc=90% to 82% when all features of the dataset are used (i.e., Model V). (ii) Precision indicates the number of actual "Yes" predictions that actually belong to all samples categorized as "Yes" class. Higher *P* reveals that "Yes" classes are better predicted than "No" classes in the classification model. Model IV is the best performer (*P*= 95.45% for five features) and can be easily visible in the figure. For the other models, *P* values are 95%, 84.62%, 84%, and 80% for Model III, Model II, Model V, and Model I, respectively. (iii) Recall is the ratio of all classes (i.e., "Yes" and "No") that are properly classified. A higher *R* value indicates that the majority of the positive classes are categorized as "Yes" classes. Model II outperformed the other models with a score of 88%, followed by 84% for Model IV, 80.77% for Model V, 80% for Model I, and 76% for Model III. (iv) F1-Score is the harmonic mean of the *R* and *P*. The higher *F1* value depicts the model is in making predictions more accurately. *F1* values of the generated models were found to be from highest to lowest as 89.36% for Model IV, 86.27% for Model II, 84.44% for Model III, 82.35% for Model V, and 80% for Model I, respectively. As a result, performance metrics indicate that the performance of Model IV is better than the other models. Moreover, Model II exhibits similar performance to Model III in the case of three and four features used. Therefore, the ϕ feature has no significant effect on the model performance, neither positive nor negative. The worst model performance in predicting slope stability is found for Model I which has the lowest feature numbers.

4. Conclusions

In this paper, a feature importance-based feature ranking and subset selection framework was presented for slope stability assessment. The Ranger algorithm was utilized during the generation of the prediction models. Feature selection was conducted manually based on the random forest FI scores and

Model I		Actual	
		Yes	No
Predicted	Yes	20	5
	No	5	20
Accuracy		0.8000	
Precision		0.8000	
Recall		0.8000	
F1-Score		0.8000	

Model II		Actual	
		Yes	No
Predicted	Yes	22	4
	No	3	21
Accuracy		0.8600	
Precision		0.8462	
Recall		0.8800	
F1-Score		0.8627	

Model III		Actual	
		Yes	No
Predicted	Yes	19	1
	No	6	24
Accuracy		0.8600	
Precision		0.9500	
Recall		0.7600	
F1-Score		0.8444	

Model IV		Actual	
		Yes	No
Predicted	Yes	21	1
	No	4	24
Accuracy		0.9000	
Precision		0.9545	
Recall		0.8400	
F1-Score		0.8936	

Model V		Actual	
		Yes	No
Predicted	Yes	21	4
	No	5	20
Accuracy		0.8200	
Precision		0.8400	
Recall		0.8077	
F1-Score		0.8235	

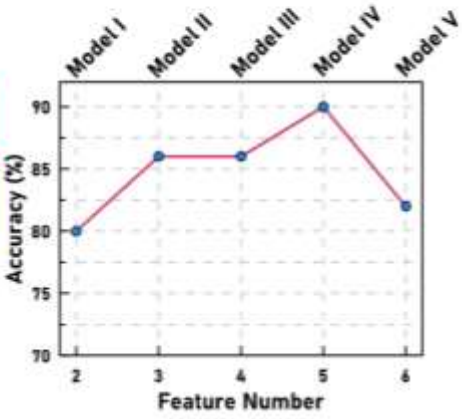


Figure 3. Performance results of five different prediction models

model performances were assessed considering the selected features to investigate the performance result of the models with various features. It is observed that the selected feature numbers affected the prediction results of the models. While Model IV achieved the highest test accuracy with a value of 90%, Model I, which has the lowest features, exhibited the worst performance in terms of performance metrics.

References

Abdalla, J. A., Attom, M. F., & Hawileh, R. (2015). Prediction of minimum factor of safety against slope failure in clayey soils using artificial neural network. Environmental Earth Sciences, 73, 5463-5477.

Alpaydin, E. (2020). Introduction to machine learning. MIT press.

Cala, M., & Flisiak, J. (2020). Slope stability analysis with FLAC and limit equilibrium methods. In FLAC and numerical modeling in geomechanics (pp. 111-114). CRC Press.

Choobbasti, A. J., Farrokhzad, F., & Barari, A. (2009). Prediction of slope stability using artificial neural network (case study: Noabad, Mazandaran, Iran). Arab J Geosci 2 (4): 311–319.

Chakraborty, A., & Goswami, D. (2017). Slope stability prediction using artificial neural network (ANN). Int. J. Eng. Comput. Sci, 6(6), 21845-21848.

Demir, S., & Sahin, E. K. (2022). Comparison of tree-based machine learning algorithms for predicting liquefaction potential using canonical correlation forest, rotation forest, and random forest based on CPT data. *Soil Dynamics and Earthquake Engineering*, 154, 107130.

Guyon, I., Gunn, S., Nikravesh, M., & Zadeh, L. A. (Eds.). (2008). Feature extraction: foundations and applications (Vol. 207). Springer.

Hoang, N. D., & Bui, D. T. (2017). Slope stability evaluation using radial basis function neural network, least squares support vector machines, and extreme learning machine. In Handbook of neural computation (pp. 333-344). Academic Press.

Hoang, N. D., & Pham, A. D. (2016). Hybrid artificial intelligence approach based on metaheuristic and machine learning for slope stability assessment: A multinational data analysis. Expert Systems with Applications, 46, 60-68.

Hobeichi, S., Abramowitz, G., Evans, J. P., & Ukkola, A. (2022). Toward a Robust, Impact-Based, Predictive Drought Metric. Water Resources Research, 58(2), e2021WR031829.

Jellali, B., & Frikha, W. (2017). Constrained particle swarm optimization algorithm applied to slope stability. International Journal of Geomechanics, 17(12), 06017022.

Kardani, N., Zhou, A., Nazem, M., & Shen, S. L. (2021). Improved prediction of slope stability using a hybrid stacking ensemble method based on finite element analysis and field data. Journal of Rock Mechanics and Geotechnical Engineering, 13(1), 188-201.

Krahn, J. (2003). The 2001 RM Hardy Lecture: The limits of limit equilibrium analyses. Canadian Geotechnical Journal, 40(3), 643-660.

Li, J., & Wang, F. (2010). Study on the forecasting models of slope stability under data mining. In Earth and Space 2010: Engineering, Science, Construction, and Operations in Challenging Environments (pp. 765-776).

Lim, K., Lyamin, A. V., Cassidy, M. J., & Li, A. J. (2016). Three-dimensional slope stability charts for frictional fill materials placed on purely cohesive clay. International Journal of Geomechanics, 16(2), 04015042.

Lin, S., Zheng, H., Han, B., Li, Y., Han, C., & Li, W. (2022). Comparative performance of eight ensemble learning approaches for the development of models of slope stability prediction. Acta Geotechnica, 17(4), 1477-1502.

Liu, Z., Shao, J., Xu, W., Chen, H., & Zhang, Y. (2014). An extreme learning machine approach for slope stability evaluation and prediction. Natural hazards, 73, 787-804.

Liu, G., Ma, J., Hu, T., & Gao, X. (2022). A feature selection method with feature ranking using genetic programming. Connection Science, 34(1), 1146-1168.

Lu, P., & Rosenbaum, M. S. (2003). Artificial neural networks and grey systems for the prediction of slope stability. Natural Hazards, 30, 383-398.

Moayedi, H., Tien Bui, D., Kalantar, B., & Kok Foong, L. (2019). Machine-learning-based classification approaches toward recognizing slope stability failure. Applied Sciences, 9(21), 4638.

Moon, J., Park, S., Rho, S., & Hwang, E. (2022). Robust building energy consumption forecasting using an online learning approach with R ranger. Journal of Building Engineering, 47, 103851.

Pham, K., Kim, D., Park, S., & Choi, H. (2021). Ensemble learning-based classification models for slope stability analysis. Catena, 196, 104886.

Sah, N. K., Sheorey, P. R., & Upadhyaya, L. N. (1994, February). Maximum likelihood estimation of slope stability. In International journal of rock mechanics and mining sciences & geomechanics abstracts (Vol. 31, No. 1, pp. 47-53). Pergamon.

Samui, P. (2008). Slope stability analysis: a support vector machine approach. Environmental Geology, 56, 255-267.

Tiyasha, T., Tung, T. M., Bhagat, S. K., Tan, M. L., Jawad, A. H., Mohtar, W. H. M. W., & Yaseen, Z. M. (2021). Functionalization of remote sensing and on-site data for simulating surface water dissolved oxygen: Development of hybrid tree-based artificial intelligence models. Marine pollution bulletin, 170, 112639.

Wang, G., Zhao, B., Wu, B., Zhang, C., & Liu, W. (2023). Intelligent prediction of slope stability based on visual exploratory data analysis of 77 in situ cases. International Journal of Mining Science and Technology, 33(1), 47-59.

Wang, L., Wu, C., Tang, L., Zhang, W., Lacasse, S., Liu, H., & Gao, L. (2020). Efficient reliability analysis of earth dam slope stability using extreme gradient boosting method. Acta Geotechnica, 15, 3135-3150.

Wright, M. N., & Ziegler, A. (2015). ranger: A fast implementation of random forests for high dimensional data in C++ and R. arXiv preprint arXiv:1508.04409.

Xiao, S., Guo, W. D., & Zeng, J. (2018). Factor of safety of slope stability from deformation energy. Canadian Geotechnical Journal, 55(2), 296-302.

Xiaoming, Y., & Xibing, L. (2011, April). Bayes discriminant analysis method for predicting the stability of open pit slope. In 2011 International Conference on Electric Technology and Civil Engineering (ICETCE) (pp. 147-150). IEEE.

Yang, X. L., & Yin, J. H. (2004). Slope stability analysis with nonlinear failure criterion. Journal of Engineering Mechanics, 130(3), 267-273.

Yang, Y., Zhou, W., Jiskani, I. M., Lu, X., Wang, Z., & Luan, B. (2023). Slope Stability Prediction Method Based on Intelligent Optimization and Machine Learning Algorithms. Sustainability, 15(2), 1169.

Zhou, K. P., & Chen, Z. Q. (2009, December). Stability prediction of tailing dam slope based on neural network pattern recognition. In 2009 Second International Conference on Environmental and Computer Science (pp. 380-383). IEEE.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 29-33, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 29-33, February 2023
Copyright © 2023 EJOSAT
Research Article

Sensing Magnetic Field with Single-Spin Dynamical Probe State: Control over Sensing Precision via Quantum Fisher Information

Sergey Borisenok[1,2*]

[1*] Abdullah Gül University, Faculty of Engineering, Department of Electrical and Electronics Engineering, Kayseri, Türkiye, (ORCID: 0000-0002-1992-628X), sergey.borisenok@agu.edu.tr

[2] Boğaziçi University, Feza Gürsey Center for Physics and Mathematics, İstanbul, Türkiye, (ORCID: 0000-0002-1992-628X), borisenok@gmail.com

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1249710)

ATIF/REFERENCE: Borisenok, S. (2023). Sensing Magnetic Field with Single-Spin Dynamical Probe State: Control over Sensing Precision via Quantum Fisher Information. *European Journal of Science and Technology*, (48), 29-33.

Abstract

Quantum sensors play an important role in many branches of modern science, and they occupy a huge segment of the growing market for quantum devices. Quantum sensors use qubits and their analogs as detecting and analyzing quantum elements. Some sensors can be based on a single qubit, which is often presented as a system making its evolution on the so-called Bloch sphere. Different criteria are used to evaluate the efficiency of the sensing process. One of the most popular is the Quantum Fisher Information Matrix (QFIM) based on Fisher information. The magnitudes of the QFIM elements are strongly related to the precision of the sensing. As an analog of the classical Cramér theorem, one can define the quantum Cramér-Rao bound for the variance V, which is equal to $V = 1/NF$ where F is the corresponding quantum Fisher information element, and N stands for the number of repeated sensory measurements. In this work, we develop our quantum Fisher information-based approach for a single feedback-driven qubit-type element for sensing external magnetic fields. We demonstrate the efficiency of our algorithm and discuss its further possible improvement. The approach developed here can be easily extended to other sensing schemes: collective spin systems and multi-qubit-based sensors. Alternative control algorithms can be applied to drive the probe state vector for maximization of the QFIM components. The particular choice of the control algorithm is defined by the specific experimental set-up.

Keywords: Quantum bit, Bloch sphere, Fisher information, Cramér-Rao bound, Quantum sensing, Feedforward control.

Tek Dönüşlü Dinamik Araştırma Durumu ile Manyetik Alanı Algılama: Kuantum Fisher Bilgileri Yoluyla Algılama Hassasiyeti Üzerinde Kontrol

Öz

Kuantum sensörleri, modern bilimin birçok dalında önemli bir rol oynar ve kuantum cihazları için büyüyen pazarın büyük bir bölümünü işgal eder. Kuantum sensörleri, kuantum öğelerini tespit etmek ve analiz etmek için kübitleri ve analoglarını kullanır. Bazı sensörler, genellikle evrimini sözde Bloch küresi üzerinde gerçekleştiren bir sistem olarak sunulan tek bir kübite dayalı olabilir. Algılama sürecinin etkinliğini değerlendirmek için farklı kriterler kullanılır. En popüler olanlardan biri, Fisher bilgilerine dayanan Kuantum Fisher Bilgi Matrisidir (KFBM). KFBM öğelerinin büyüklükleri, algılama hassasiyeti ile güçlü bir şekilde ilişkilidir. Klasik Cramér teoreminin bir benzeri olarak, $V = 1/NF$'ye eşit olan V varyansı için kuantum Cramér-Rao bağı tanımlanabilir; burada F, karşılık gelen kuantum Fisher bilgi öğesidir ve N, tekrarlanan duyusal ölçümlerin sayısını temsil etmektedir. Bu çalışmada, harici manyetik alanları algılamak için tek bir geri bildirim odaklı kübit tipi eleman için kuantum Fisher bilgi tabanlı yaklaşımımızı geliştirmekteyiz. Algoritmamızın verimliliğini göstermekte ve olası iyileştirmelerini tartışmaktayız. Burada geliştirilen yaklaşım, toplu döndürme sistemleri ve çoklu kübit tabanlı sensörler gibi diğer algılama şemalarına kolayca genişletilebilmektedir. KFBM bileşenlerinin maksimize edilmesi için araştırma durumu vektörünü sürmek üzere alternatif kontrol algoritmaları uygulanabilir. Kontrol algoritmasına özgü yapılacak seçim belirlenen deneysel düzenek tarafından tanımlanır.

Anahtar Kelimeler: Kuantum biti, Bloch küresi, Fisher bilgisi, Cramér-Rao sınırı, Kuantum algılama, İleri besleme kontrolü.

[*] Corresponding Author: sergey.borisenok@agu.edu.tr

1. Introduction: Quantum Fisher Information for Sensing

Quantum sensors play an important role in many branches of modern science: photonics, microscopy, gravitational wave detecting, and others (Laurenza et al., 2018; Koppenhöfer et al., 2022); they occupy a huge segment of the growing market for quantum devices (ReportLinker, 2022).

Quantum sensors use qubits and their analogs (Nielsen and Chuang, 2004) as detecting and analyzing quantum elements (Degen et al., 2017). Some sensors can be based on a single qubit, which is often presented as a system making its evolution on the so-called Bloch sphere (Bloch, 1946).

Different criteria are used to evaluate the efficiency of the sensing process. One of the most popular is the Quantum Fisher Information Matrix (QFIM) based on Fisher information (Fisher, 1922). In the quantum case, it can be defined via the Bures or, alternatively, the Hellinger distance between quantum states (Zhong et al., 2013). Here we use the Bures metric.

For the vector parameter **x** encoding the density matrix $\rho(\mathbf{x})$, the components of QFIM are defined as (Amari and Nagaoka, 2000):

$$F_{ab} = \mathrm{Tr}\left(L_b \frac{\partial \rho}{\partial x_a} \right) = -\mathrm{Tr}\left(\rho \frac{\partial L_b}{\partial x_a} \right); \quad (1)$$

and for the diagonal elements as:

$$F_{aa} = \mathrm{Tr}\left(\rho L_a^2\right). \quad (2)$$

Here the sub-indices a,b numerate the elements of **x**, and L_a denotes the symmetric logarithmic derivative for the component x_a. This derivative is a Hermitian operator with the expected value $\mathrm{Tr}(\rho L_a) = 0$; and in general case it is defined for the density matrix ρ and an operator A as (Braunstein and Caves, 1994):

$$i[\rho, A] = \frac{1}{2}\{\rho, L(A)\}, \quad (3)$$

with the commutator $[X,Y] = XY - YX$, and anticommutator $\{X,Y\} = XY + YX$. For (1)-(2) one should take (Liu et al., 2019):

$$\frac{\partial \rho}{\partial x_a} = \frac{1}{2}(\rho L_a + L_a \rho). \quad (4)$$

The magnitudes of the QFIM elements are strongly related to the precision of the sensing. As an analog of the classical Cramér theorem (Cramér, 1946), one can define the quantum Cramér-Rao bound (Nielsen, 2013) for the variance V, which is equal to:

$$V = \frac{1}{NF}, \quad (5)$$

where F is the corresponding quantum Fisher information matrix element, and N stands for the number of repeated sensory measurements.

In this work, we develop our quantum Fisher information-based approach (Borisenok, 2018) for a single feedback-driven qubit-type element for sensing external magnetic fields. We demonstrate the efficiency of our algorithm and discuss its further possible improvement.

2. Quantum Sensing of An External Magnetic Field

Let's consider a magnetic field vector **B** represented by the spherical coordinate set of one magnitude B and two angles θ and φ as ($B\cdot\cos\theta\cdot\cos\varphi$, $B\cdot\cos\theta\cdot\sin\varphi$, $B\cdot\sin\varphi$). Here we suppose also for simplicity that one angle, let's say φ, is known (Liu et al., 2019), such that our sensing deals with the estimation of B and θ.

The magnetic field detection in this case may be organized via alternative algorithms:

- A single-spin system (Pang and Brun, 2014; Liu et al., 2015);
- Collective spin system (Jing et al., 2015);
- Two-qubit system: a probe qubit serves as a sensing element, while the companion *ancilla* qubit does not interact with the magnetic field (Yuan, 2016).

Surely, the single-qubit sensing setup is the simplest from the point of its experimental realization. The interaction part of its Hamiltonian is given by $H_{\mathrm{int}} = -B\cdot\mathbf{n_0}\cdot\boldsymbol{\sigma}$, where

$$\mathbf{n}_0 = (\cos\theta, 0, \sin\theta), \quad (6)$$

and the vector $\boldsymbol{\sigma}$ consists of the Pauli matrix components $(\sigma_x,\sigma_y,\sigma_z)$. Then the QFIM can be represented via the Hamiltonian components (Pang and Brun, 2014; Liu et al., 2015):

$$\begin{aligned} H_B &= t\mathbf{n_0}\cdot\boldsymbol{\sigma}; \\ H_\theta &= -\frac{1}{2}\sin(Bt)\mathbf{n_1}\cdot\boldsymbol{\sigma} \end{aligned} \quad (7)$$

in the form (Liu et al., 2019):

$$\begin{aligned} F_{BB} &= 4t^2\left[1-(\mathbf{n_0}\cdot\mathbf{r_p})^2\right]; \\ F_{\theta\theta} &= \sin^2(Bt)\left[1-(\mathbf{n_1}\cdot\mathbf{r_p})^2\right]; \\ F_{B\theta} &= 2t\sin(Bt)(\mathbf{n_0}\cdot\mathbf{r_p})(\mathbf{n}_1\cdot\mathbf{r_p}), \end{aligned} \quad (8)$$

Here:

$$\mathbf{n_1} = (\cos(Bt)\sin\theta, \sin(Bt), -\cos(Bt)\cos\theta), \quad (9)$$

and $\mathbf{r_p}$ is the Bloch vector of the probe state.

Eqs (8) demonstrate the main handicap of the sensing with a single spin: the algorithm maximizes the Fisher matrix components F_{BB} and $F_{\theta\theta}$ when the probe state vector $\mathbf{r_p}$ is

orthogonal to both vectors $\mathbf{n_0}$ and $\mathbf{n_1}$. But in this case, the component $F_{\theta\theta}$ is bounded by the sine. Another handicap is the periodical vanishing of the components $F_{\theta\theta}$ and $F_{B\theta}$, when $\sin(Bt)$ becomes equal to 0.

As we mentioned above, the two-qubit sensing could be an option for precision improvement, but here we focus on the alternative approach for a single sensing element: making the probe state vector to be controlled to maximize the Fisher information components. In other words, we describe here the case of dynamical $\mathbf{r_p}$ in the place of a static one.

3. Sensing Magnetic Field with a Single Spin by A Dynamical Probe State

For single-qubit-based quantum sensors, optimal and sub-optimal feedback (closed-loop) control has already been studied in (Borisenok, 2018; Poggiali et al., 2018).

Here we develop our approach (Borisenok, 2018), which also used the evaluation criteria based on the Fisher information, to adapt it to the efficient sensing of an external magnetic field. We apply here a feedforward (open-loop) form of the control taking the dynamical probe state vector $\mathbf{r_p}(t)$ as a control parameter.

To do it, let's express the probe state vector via the angle parameter $\theta_p(t)$ as:

$$\mathbf{r_p} = \left(\cos\theta_p(t), 0, \sin\theta_p(t)\right) \tag{10}$$

(the magnitude of the vector is equal to 1).

By (10) and (6),(9) one can present the vectors $\mathbf{n_0}$, $\mathbf{n_1}$ in the form:

$$\begin{aligned} &\mathbf{n}_0 \cdot \mathbf{r_p} = \cos(\theta - \theta_p(t)) ; \\ &\mathbf{n}_1 \cdot \mathbf{r_p} = \cos(Bt)\sin(\theta - \theta_p(t)) . \end{aligned} \tag{11}$$

The system (8) becomes:

$$\begin{aligned} &F_{BB} = 4t^2\left[1 - \cos(\theta - \theta_p(t))\right]^2 ; \\ &F_{\theta\theta} = \sin^2(Bt)\left[1 - \cos(Bt)\sin(\theta - \theta_p(t)\right]^2 ; \\ &F_{B\theta} = 2t\sin(Bt)\cos(Bt)\sin(\theta - \theta_p(t))\cos(\theta - \theta_p(t)) . \end{aligned} \tag{12}$$

Now let's focus on F_{BB} and $F_{\theta\theta}$. From (12) one can learn easily that the maximization of both of them simultaneously has a conflict: different trigonometrical contributions from the variable θ. For this reason, we organize the controlled algorithm for θ_p in two stages: at the first stage we focus on the measurement of the amplitude B, and at the second one – on the angle variable θ.

At the first stage, we define the feedforward control as: $\theta_p = \nu t$, where the control frequency $\nu >> B$, such that it covers all minima and maxima of $\sin(Bt)$ (it will be important for the second stage).

From now we rescale the time variable t in the dimensionless units: νt, and the magnetic field amplitude is expressed in the dimensionless units B/ν (which must be <1). The Fisher information for F_{BB} is limited by the growing magnitude $4t^2$, and in principle, it is increasing virtually for all ranges of θ_p, apart from the values close to the magnetic field angle θ. Having few measurements N, one can achieve good precision of the variance (5).

In the second stage, we suppose to know the amplitude B, and we start this stage from an integer moment $t = n$ (which starts close to $\sin(Bt) = 0$ due to the magnetic field scaled in the ν units is: $B << 1$). We need to measure the angle θ close to the moment of the maximum for $F_{\theta\theta}$ for the given B.

The maximum magnitude of $\cos(Bt)$ corresponds to:

$$\cos(Bt) = \max\left\{\frac{1}{3\sin(\theta - \theta_p)}\left(1 \pm \sqrt{1 + 3\sin^2(\theta - \theta_p)}\right), 1\right\} . \tag{13}$$

For the numerical evaluation, we chose $\theta = \pi/4$ and $B = 0.2$ (in the dimensionless units of ν). Then the plot for the Fisher information F_{BB} is given in Figure 1 (the first stage):

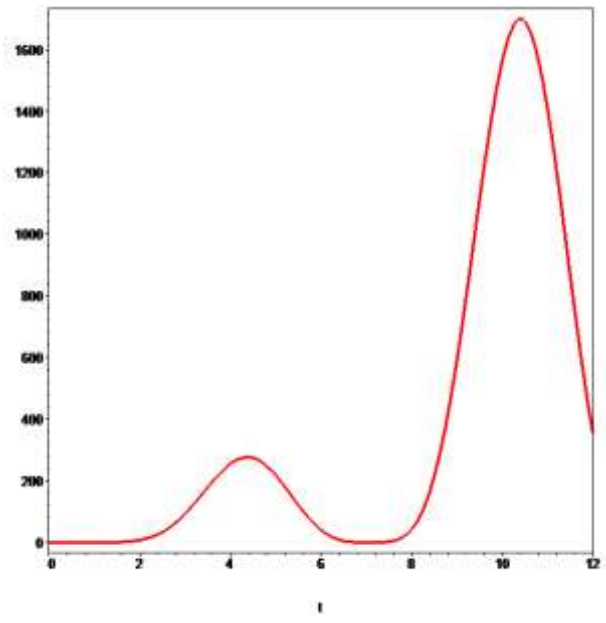


Figure 1. The Fisher information F_{BB} vs time t.

In Fig.1 one can easily observe the achievement of the maximum for the magnetic field amplitude Fisher information F_{BB} around $t = 10$. A similar investigation for the maximum we do for the magnetic field angle Fisher information $F_{\theta\theta}$.

For the second stage, we obtain Figure 2:

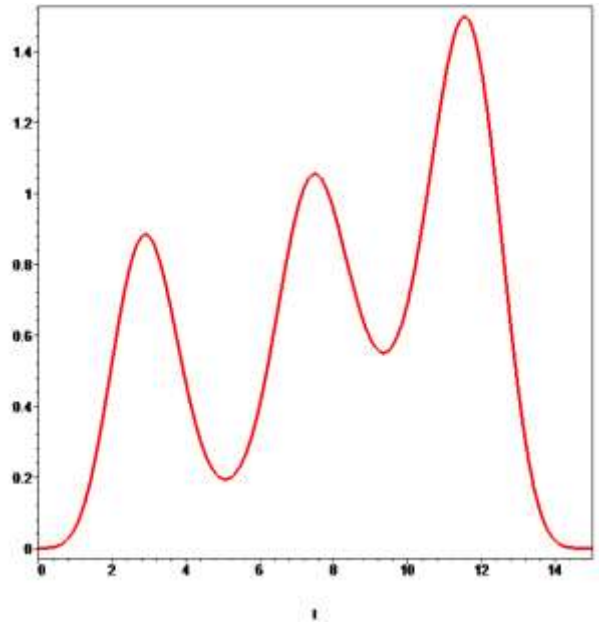


Figure 2. The Fisher information $F_{\theta\theta}$ vs time t.

Thus, for the first stage, the measurements are taken around the time moment t = 10, and for the second stage – around t = 11.

4. Results and Discussion

We develop a dynamical algorithm for the maximizing of the Fisher information in the process of detecting the amplitude and the angle of an external magnetic field. Our algorithm is numerically simple, open-loop and provides the best optimization of the variance parameters for single-spin measurements.

Alternative control algorithms can be applied to drive the vector $\mathbf{r_p}$ for maximization of the QFIM components. The particular choice of the control algorithm is defined by the specific of the experimental set-up and by the compromise between the precision of the control goal achievement and the optimization of the numerical complexity.

Algorithms for the quantum detecting and evaluation of the magnetic fields also work for other sensing applications: quantum photonics, renewable energy, nuclear and geothermal energy, and many others (Crawford et al., 2021).

5. Conclusions and Recommendations

Open-loop algorithm based on a single spin/qubit measurements is able to provide a good variance of the measurements for external fields due to the maximization of the quantum Fisher information.

Our approach can be extended for more advanced algorithms including different closed-loop realizations: optimal feedback, gradient methods, and forming target attractors in the dynamical system (Fradkov, 2007; Kolesnikov, 2014; Pechen et al., 2022). It also can be easily extended to other sensing schemes: collective spin systems and multi-qubit-based sensors.

The effects related to quantum sensing at finite temperatures (Wu and Shi, 2021) should be studied additionally.

6. Acknowledge

This work was supported by the Research Fund of Abdullah Gül University; Project Number: BAP FBA-2023-176 “Geribesleme kontrol algoritmaları ile kubit tabanlı sensörlerin verimliliğinin artırılması”.

References

Amari, S., Nagaoka, H. (2000). *Methods of Information Geometry*, Providence, USA: American Mathematical Society.

Bloch, F. (1946). Nuclear induction, *Physical Review*, 70, 460-474.

Borisenok, S. (2018). Control over performance of qubit-based sensors, *Cybernetics and Physics*, 7(3), 93-95.

Braunstein, L. V., Caves, C. M. (1994). Statistical distance and the geometry of quantum states, *Physical Review Letters*, 72, 3439-3443.

Cramér, H. (1946). *Mathematical Methods of Statistics*, Princeton Mathematical Series, Princeton, USA: Princeton University Press.

Crawford, S. E., Shugayev, R. A., Paudel, H. P., Lu, P., Syamlal, M., Ohodnicki, P. R., Chorpening, B., Gentry, R., Duan, Y. (2021). Quantum sensing for energy applications: Review and perspective, *Advanced Quantum Technologies*, 4(8), 2100049.

Degen C. L., Reinhard, F., Cappellaro, P. (2017). Quantum sensing, *Review of Modern Physics*, 89, 035002.

Fisher, R. A. (1922). On the mathematical foundations of theoretical statistics, *Philosophical Transactions of the Royal Society of London, Series A*, 222, 309-368.

Fradkov, A. L. (2007). *Cybernetical Physics. From Control of Chaos to Quantum Control*, Berlin, Heidelberg, Germany: Springer.

Jing, X. X., Liu, J., Xiong, H. N., Wang, X. (2015). Maximal quantum Fisher information for general su(2) parametrization processes, *Physical Review A*, 92, 012312.

Kolesnikov, A. A. (2014). *Introduction of synergetic control*, 2014 American Control Conference, Portland, USA, 3013-3016.

Koppenhöfer, M., Groszkowski, P., Lau, H., Clerk, A. A. (2022). Dissipative superradiant spin amplifier for enhanced quantum sensing, *PRX Quantum*, 3, 030330.

Laurenza, R., Lupo, C., Spedalieri, G., Braunstein, S. L., Pirandola, S. (2018). Channel simulation in quantum metrology, *Quantum Measurements and Quantum Metrology*, 5, 1-12.

Liu, J., Jing, X., Wang, X. (2015). Quantum metrology with unitary parametrization processes, *Scientific Reports*, 5, 8565.

Liu, J., Yuan, H., Lu, X., Wang, X. (2019). Quantum Fisher information matrix and multiparameter estimation, *Journal of Physics A: Mathematical and Theoretical*, 53(2), 023001.

Nielsen, F. (2013). *Cramer-Rao lower bound and information geometry*, In: R. Bhatia, C. S. Rajan, A. I. Singh, Eds, Connected at Infinity II. Texts and Readings in Mathematics, vol 67. Gurgaon, India: Hindustan Book Agency.

Nielsen, M. A., Chuang, I. L. (2004). *Quantum Computation and Quantum Information*, Cambridge, UK: Cambridge University.

Pang, S., Brun, T. A. (2014). Quantum metrology for a general Hamiltonian parameter, *Physical Review A*, 90, 022117.

Pechen, A. N., Borisenok, S., Fradkov, A. L. (2022). Energy control in a quantum oscillator using coherent control and engineered environment, *Chaos, Solitons & Fractals*, 164, 112687.

Poggiali, F., Cappellaro, P., Fabbri, N. (2018). Optimal control for one-qubit quantum sensing, *Physical Review X*, 8, 021059.

ReportLinker. (2022). The Global Quantum Sensors Market size is expected to reach $619.8 million by 2028, rising at a market growth of 16.4% CAGR during the forecast period. [Online]. Available: https://www.globenewswire.com/news-release/2022/11/22/2561070/0/en/The-Global-Quantum-Sensors-Market-size-is-expected-to-reach-619-8-million-by-2028-rising-at-a-market-growth-of-16-4-CAGR-during-the-forecast-period.html

Wu, W., Shi, C. (2021). Criticality-enhanced quantum sensor at finite temperature, *Physical Review A*, 104, 022612.

Yuan, H. (2016). Sequential feedback scheme outperforms the parallel scheme for Hamiltonian parameter estimation, *Physical Review Letters*, 117, 160801.

Zhong, W., Sun, Z., Ma, J., Wang, X., Nori, F. (2013). Fisher information under decoherence in Bloch representation, *Physical Review A*, 87, 022337.

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 34-39, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 34-39, February 2023
Copyright © 2023 EJOSAT
Research Article

Baghdad Vehicle Traffic Congestion: Case Study

Salim A. Mohammed Ali[1*], Emad H. Al-Hemiary [2]

[1*] Al-Nahrain University, Faculty of Information Engineering, Departmant of Computer Networks Engineering, Baghdad, Iraq, (ORCID: 0000-0002-1701-464X), salimm@nahrainuniv.edu.iq

[2] Al-Nahrain University, Faculty of Information Engineering, Departmant of Computer Networks Engineering, Baghdad, Iraq, (ORCID: 0000-0002-1564-0479), emad@coie-nahrain.edu.iq

(1st International Conference on Frontiers in Academic Research ICFAR, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.)

ATIF/REFERENCE: Ali, S. A. M. & Al-Hemiary, E. H. (2023). Baghdad Vehicle Traffic Congestion: Case Study. *European Journal of Science and Technology*, (48), 34-39.

Abstract

Vehicles contribute a considerable amount of green gas emission to the environment. Methods of calculating such emission using conventional measuring tools do not give an accurate future estimation as the number of vehicles increases, since there are many factors that affect the estimation such as traffic delays. Therefore, a different approach is should be considered in measuring road networks traffic capacity for a specific region, especially when the numbers of vehicles change dramatically during rush hours. Furthermore, the amount of fuel consumption wastage during traffic delays cannot be easily calculated based of on the number of vehicles solely. In this paper, a comprehensive study is made to examine and to calculate the effect of traffic congestion in Baghdad city of Iraq in terms of: pollution, fuel consumption, and time cost, using the road network simulator of SUMO. Several scenarios are considered with randomly selected paths for each vehicle. In this study, several empirical equations are extracted from the simulation test results. As a result, an aberration is observed in fuel consumption and traffic delays while exceeding 100 thousand vehicle capacity for the whole city of Baghdad. However, the interpolated equations can be used to approximately measure the traffic metrics for higher number of vehicles for the same city.

Keywords: Congestion, Road Traffic, SUMO, V2X, Gas Emission.

Bağdat Araç Trafiği Sıkışıklığı: Vaka Çalışması

Öz

Taşıtlar çevreye önemli miktarda yeşil gaz emisyonuna katkıda bulunur. Geleneksel ölçüm araçları kullanılarak bu tür emisyonları hesaplama yöntemleri, trafik gecikmeleri gibi tahmini etkileyen birçok faktör olduğundan, araç sayısı arttıkça doğru bir gelecek tahmini vermemektedir. Bu nedenle, özellikle trafiğin yoğun olduğu saatlerde araç sayısı önemli ölçüde değiştiğinde, belirli bir bölge için karayolu ağlarının trafik kapasitesinin ölçülmesinde farklı bir yaklaşım düşünülmelidir. Ayrıca, trafik gecikmelerinde yakıt sarfiyatı israfının miktarı sadece araç sayısına göre kolayca hesaplanamamaktadır. Bu bildiride, Irak'ın Bağdat şehrinde trafik sıkışıklığının kirlilik, yakıt tüketimi ve zaman maliyeti açısından etkisini SUMO'nun yol ağı simülatörü kullanılarak incelemek ve hesaplamak için kapsamlı bir çalışma yapılmıştır. Her araç için rastgele seçilen yollarla çeşitli senaryolar dikkate alınır. Bu çalışmada, simülasyon testi sonuçlarından çeşitli ampirik denklemler çıkarılmıştır. Sonuç olarak, Bağdat şehrinin tamamı için 100 bin araç kapasitesi aşılırken, yakıt tüketiminde ve trafik gecikmelerinde bir sapma gözleniyor. Bununla birlikte, enterpolasyonlu denklemler, aynı şehir için daha fazla sayıda araç için trafik ölçümlerini yaklaşık olarak ölçmek için kullanılabilir.

Anahtar Kelimeler: Sıkışıklık, Karayolu Trafiği, SUMO, V2X, Gaz Emisyonu.

1. Introduction

Many metropolitan cities around the world have issues of traffic congestion in specific hours of a day, rush hours, as a result of huge number of vehicles operating at the same time. To pinpoint the congestion reasons, complete traffic studies are made to collect useful information about the behavior of such congestions. These studies will be useful to find appropriate solutions to reduce the amount of traffic congestion such as: efficient traffic management system, new road planning, intelligent traffic systems, especially V2X (Vehicle-to-Everything) world is blooming (Ali & Al-Hemiary, 2021).

In this paper, a study is made to give useful information about how traffic congestion is variant as the number of vehicles are increasing, and how vehicle trip numbers increment will increase the greenhouse gas emissions exponentially, plus the amount of unneeded fuel consumption due to traffic flow congestions. Baghdad city is chosen because it is considered one of the largest urban cities in the region with population exceeds 8 million capita (WP, 2023), with number of vehicles registered in the city above 2.7 million (COSIT, 2023), (see Fig. 1). Sumo simulation tool is used to conduct the road simulations. Other tools used to extract the road information, build vehicle networks, and finding the best routes.

Thus, future traffic congestion effects can be speculated and how new technologies, V2X applications and services can be beneficial to overcome and reduce the issues produced by traffic congestions (Ali & Al-Hemiary, 2020). The following section include the main objectives of the study, then followed by similar studies for other cities around the world. After then, the main study metrics are explained, followed by study results and observations..

The main objective of this study can be summarized in the following list:

- To justify the purpose of the paper, as the problem statement states how vehicles contribute a significant amount of world greenhouse gas pollution.

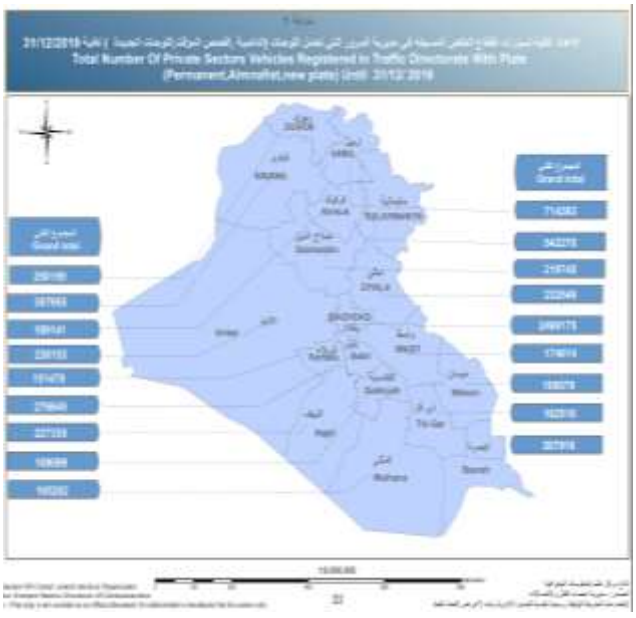


Fig. 1. Vehicles numbers in Iraq governorates till 2020

- To measure the capacity of the road network of the city and when it will be congested at most.
- To produce approximate evaluation and mathematical equations that describes the behavior of the road network as the tremendous increasing of vehicles inside the city (Baghdad City, specifically speaking). Thus that, future speculation can be easily computed.
- The study results will be beneficiary to vehicular network planning and identify the mobile network capacity in terms of latency, data rate, and number of telecommunication towers.
- The study will evaluate the economic cost and loss of revenue due to the inefficient use of roads and excessive use of fuel that if utilized properly a significant amount will be saved.

Several associated studies were adopted around the world to study the urban traffic network congestions for planning and evaluations. In (Alshaya et al., 2019), the paper emphases on the various road traffic simulation software including (Sumo) that are used by many researchers to find useful statistics of studying traffic of the city of Rome. In (Schweizer et al., 2021), a large-scale simulation has been made for the city of Bologna (Italy). The simulation covers pedestrians, bikes, scooters, and other vehicles in rush hours using (Sumo) simulation tool. In (Khumara, 2018), similar simulation has been conducted to build the smart city concept, through devising intelligent traffic systems (ITS). Similar simulation tools used to determine road congestion bottlenecks, and measure the optimum vehicle speeds to present better traffic configurations.

The rest of the paper includes the study metrics, followed by tools used in the study, and then the study steps that had been carried out. The results and discussion in the following section, and the last section concludes the paper.

2. Material and Method

2.1. Lıterature Revıew

Baghdad is the capital of Iraq, and it considered as one with the largest population of the country. Thus, Baghdad is a good example that suffers from excessive traffic congestion compared to other cities in the region. Likewise, the researcher in (Alshaya et al., 2019) worked extensively to reduce the traffic congestion in Rome, which suffers from traffic congestion distinctively by analyzing the source of the congestion through several experiments and simulations. Other related research works conducted by (Barrachina et al. , 2014) and (Benner et al., 1993), which is basically exploiting computer tools to perform accurate simulations. In (Fontaras et al., 2015) some work done to evaluate the source of CO2 emission from vehicles by plotting a model for it. Also, through using specific junction simulation, (Strohmandl et al., 2015) have presented a method of light controlling of the traffic.

As the part of solving problems of traffic congestions. Some researchers were successful to develop simulation scenarios by using objective analysis, i.e., conducting manual survey, and collecting real data by monitoring and observing. In this way, a direct approach is taken to identify the problems and finding the perfect solution for it. In (Ma et al., 2014), they integrate some road network metrics to build a calibration model to deliver some measurements that cannot be taken from direct management. In (Bieker-Walz et al., 2015), they have used a similar approach of

what we perform in this paper for the city of Bologna, Italy. Similarly, (Vent, 2015) have conducted similar approaches to build a simulation package for the city of Dublin, Ireland by using real data of the past few years. In (Huang et al., 2014), a simulation study is conducted for vehicles that are accessing highways by using variate speed limits, so they can analyse vehicle crash rates

2.2. Study Metrıcs

In this section, road traffic metrics that are essential to the simulation are presented and explained. These metrics identifies the main problems and issues of traffic networks that can be mitigated or avoided through using more efficient traffic controls and configurations. The following traffic metrics are used in this study:

- Trip Duration (seconds): each vehicle trip has a starting point and destination point within the map. This metric defines the amount of time required the vehicle to reach its destination through following the roads in a simulated map. The trip duration measures all the delays that might the vehicle faces during the trip such as, traffic light waiting (planned waiting), slow traffic motion (lower speed than usual), traffic congestion time loss. This metric is very important in measuring the traffic flow rates in a specific area.

- Route Length (meters): This metric measures the distance the vehicle travelled to reach its destination. The route is pre-calculated by another tool, which uses the shortest path to accomplish the route.

- Time Loss (seconds): This metric measures the time lost due to driving under the speed limit. In other words, the value of time loss should be equal to zero if normal traffic flow is considered.

- Emissions (mg): the mass of the various gases is emitted while driving the vehicle. Types of emission include the following gases: CO2, CO, NOx, PMx, and HC.

- Fuel (ml): the amount of fuel consumed while finishing the trip in (letter). Hence, all vehicles are considered to be using the same fuel, which gasoline.

2.3. Study Steps

In this section, the previous metrics are applied for the city of Baghdad (Iraq), such that, the whole map with all streets and road networks included are extracted from Open Street Map (OSM) website, which an open-source websites that provides geographical areas in XML format with road networks for researches. The road network of the city is shown in the Fig. 2.

The second step is to generate traffic networks of trips. Five networks are generated starting with 50 thousand trips and increasing by 50 thousand for bigger networks till reaching 250 thousand trips, which is more than the capacity of the city. The start and end points of trips are selected randomly, so unbiased results can be obtained. NetworkGen tool is used to accomplish this step.

Fig. 2. City of Baghdad (Iraq) map of roads network of most municipalities.

The third step is calculating the best route for each trip, for the start point to the arrival destination. Dijkstra algorithm is used for route calculation. This means all vehicles will take the shortest path with minimal fuel consumption; however, traffic congestion is not considered in the calculation, because it is undetermined, since all trips are generated randomly. Duaroute tool is used to calculate the shortest routes for each trip aside.

The fourth step, is to apply the routes to the map and measure the metrics for each trip alone. Sumo tool is used to accomplish this task. The simulation process is repeated for 5 networks with sizes of: 50K, 100K, 150K, 200K, and 250K trips. In each simulation, all the metrics mentioned previously are measured individually for each vehicle (trip). The following section shows the aggregated results of each trip.

2.4. Study Steps

To prepare for the simulation many tools are used to build simulation environment such as maps, roads, traffic, etc. And then this environment is used for V2X simulation (vehicles sent packets to the nearest base station). The following subsections introduces and explain the purpose of each tool.

- OpenStreetMap

OpenStreetMap (OSM) is an online available database of maps with road networks. It almost covers most cities and urban areas. Researchers and users can download regions of the map as an OSM map format which is in XML format. Large regions such as big cities require to download large amount of information which might exceed the capability of the online tool to download large sized regions. Other 3rd party tools are required to be used to access this information. OSM maps are editable and a user can easily modify the data to achieve specific endeavor. This tool is used to download the full road network map of Baghdad (used for the study of the next section), and small sized region of the city to be use in V2X simulation, since larges maps cannot be handled by mobile network simulators (Anonymous, 2017).

- JOSM

Java OSM is a helpful tool build by Java programming language, to edit and create OSM maps. Sometimes the download maps are outdated and streets or bridges are missing because of recent construction. This tool is used to correct the glitches and correct the road sizes in terms of direction (one-way or two-way) and number of lanes (Street width). Most of the roads were correct and modifications are required. Also, the tool is used to convert the OSM map into an accessible format by the other tools such as SUMO (Lopez et al., 2018).

- SUMO

SUMO, stands for Simulation of Urban Mobility, is vehicular traffic simulator developed in 2001 and since then it was upgraded many times to be compatible the world changes such as it is now supporting electrical car mobility. The tool was used to deploy various type of vehicular traffics into a specific map, and the simulator will generate useful output in many aspects. The generated log can be pre-assigned so the simulation will not take long time. Simulations of large maps usually takes a significant amount of time and sometimes the simulation crashes when there are no enough resources such: computer memory (RAM), or processing power (CPU). Therefore, careful measures should be taken before running the simulation.

3. Results and Discussion

3.1. Results

In this section, all the results obtained from the 5 simulations are presented. Each metric is presented separately based on each network size simulation. Fig. 3 shows the total road trips of all vehicles (trips) for the entire simulation. It is obvious from the results the graph appeared linearly, since, all trips are random and the increment of trips are equi-spaced in behavior. The empirical equation generated by the Exel software from the graph is,

$$y = 699724x - 22559 \qquad \text{(eq. 1)}$$

Where (y) represents the total trip length, while (x) represents the number of trips.

The duration of each trip is summed up to obtain the total duration of all trips conducted in each simulation aside. The total duration of all trips will explicitly show the period of time that vehicles were running. Fig. 4 shows the graph of the total duration. It is obvious how the graph has an aberration when the network size increased more than 100K trips, this means that the network capacity cannot handle smooth traffic, and more congestion will be on junctions, plus more wasted waiting time for vehicles.

The generated curve is a second-degree polynomial,

y = 6E+07x2 + 4E+07x - 4E+07 (eq. 2)

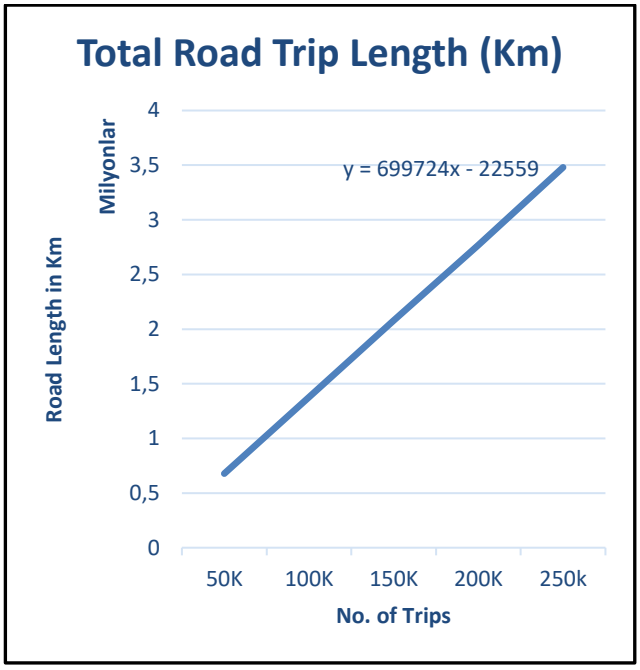


Fig. 3. Total road trips length for each simulation.

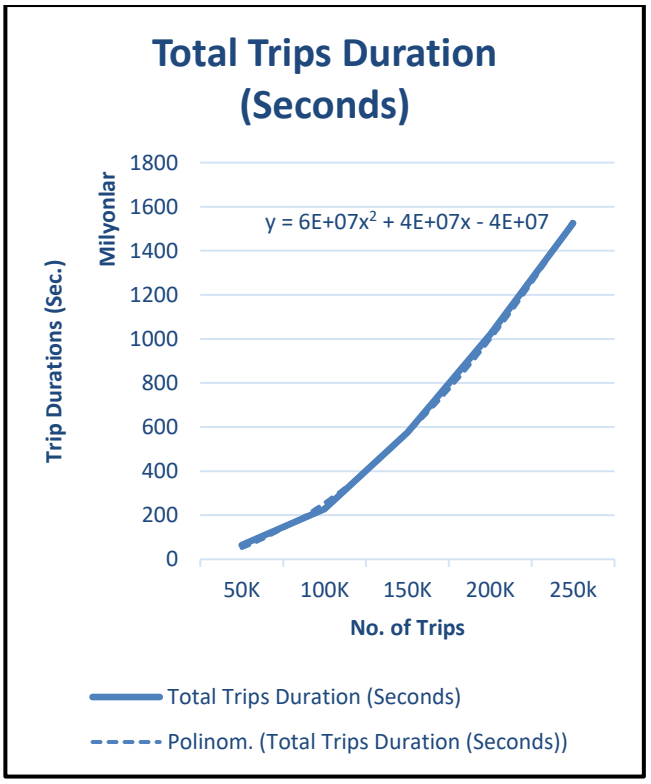


Fig. 4. Total traffic time loss in the network.

The simulation also measured the traffic time loss for each trip, waiting and stop time that is not supposed to be happen, such as heavy traffic congestion; however, waiting at a traffic light in junctions are not included in the measurement, in other words, the time loss is pure wasted time. Fig. 5 shows the graph related to the time loss for all 5 simulations. The generated polynomial from the graph is,

y = 5E+07x2 + 1E+07x - 4E+07 (eq. 3)

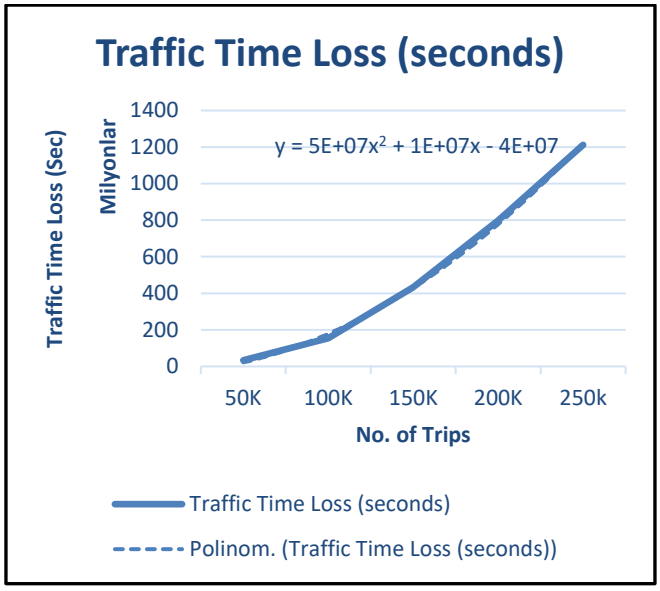


Fig. 6. Total traffic time loss in the network.

The fuel consumption is one of the most important metrics to measure, because it directly related to the total loss of revenue in traffic congestion, plus the amount of unnecessary pollution. Fig. 6 shows the graph of total fuel consumption of all vehicles in all simulations. The generated polynomial from the graph.

$$y = 49354x2 + 73240x - 41814 \quad \text{(eq. 4)}$$

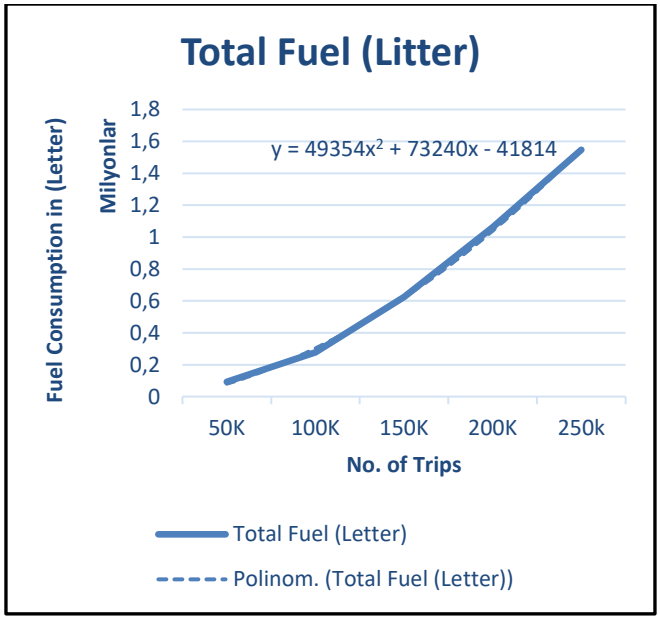


Fig. 5. Total Fuel Consumption in Letters.

The generated gas emission, which is combination of various types of greenhouse gas as shown in Table 1, is considered the amount of pollution being released to the atmosphere, which is the major reason of climate change and global warming. The total emissions of all vehicles within same simulation are aggregated and shown in Fig. 7.

TABLE I. THE AMOUNT OF EACH TYPE OF GAS IN EACH SIMULATIONS.

Trips	CO2(Kg)	CO(Kg)	HC (Kg)	NOx (Kg)	Total Emission (Kg)
50K	215477	6694	35.7	90.95	222298.4
100K	645481	26691	137	280.2	672590.31
150K	1453509	70579	356	643.1	1525087.8
200K	2469900	127777	640	1101.98	2599420.6
250k	3599365	191977	959	1612.58	3793915.3

The generated polynomial for graph is as follows:

$$y = 122160x2 + 174046x - 103236 \quad \text{(eq. 5)}$$

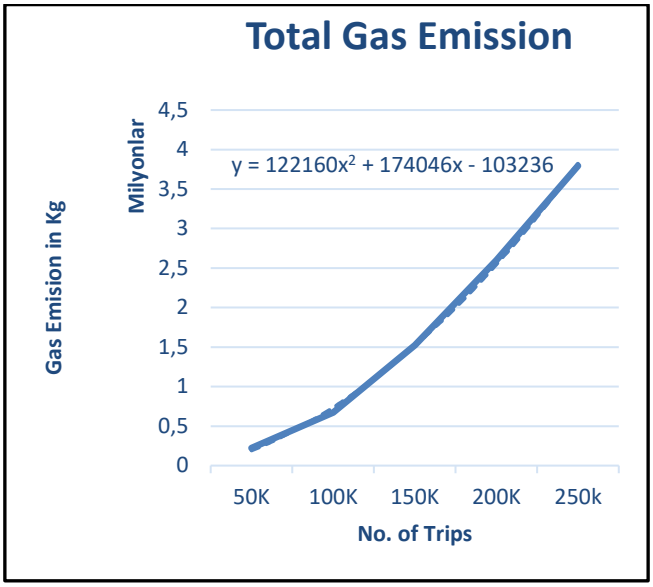


Fig. 7. Total Gas Emission in Kilograms.

3.1. Disscution

As can be seen in the results, the amount of total trips that each traffic metric is tested is between 50 k to 250k. Since the graphs showed a steady-state after 100K trips aberration, there will be no need to increase the number of trips furthermore. The abberation of the curve happens when the number of trips exceeded the 100K limit, which indicates the Baghdad city road networks capacity limit without significant delays in each trip.

4. Conclusions and Recommendations

As a conclusion, a comprehensive study is made to show the effect of increasing number of vehicles to traffic congestion. All the results indicate an aberration as the number of vehicles in the network exceeds 100 thousand. This means the total tolerable capacity of the city is below this number. These results also benefit the design of V2X systems, since it provides the necessary information about the vehicle distribution and network capacity. The same method can be applied to other cities through making proper changes to the simulation parameters.

It is recommended to use the same method to construct data models for crowded cities around the world. These data models can be useful to city road design and future traffic congestion predictions.

References

Salim, A., Ali, M., & Al-Hemairy, E. H. (2021). Communication Module for V2X Applications using Embedded Systems. Journal of Physics: Conference Series, 1933(1), 012112. doi:10.1088/1742-6596/1933/1/012112.

World Population (2023, February 1). Baghdad Population 2021. World Population Review. Retrieved February 1, 2023, from https://worldpopulationreview.com/world-cities/baghdad-population

COSIT (2023, January 1). Private Vehicle's Report 2019. Retrieved January 1, 2023, from http://cosit.gov.iq/ar/2015-11-23-08-05-11

Mohammed Ali, S. A. ., & Al-Hemairy, E. H. (2020). MINIMIZING E2E DELAY IN V2X OVER CELLULAR NETWORKS: REVIEW AND CHALLENGES. Iraqi Journal of Information and Communication Technology, 2(4), 31–42. https://doi.org/10.31987/ijict.2.4.79

Alshaya, S., Al-Saleh, A., & Hassan, M. (12 2019). USING SUMO TRAFFIC SIMULATOR: A REALISTIC TRAFFIC SIMULATION FROM THE CITY OF ROME.

Schweizer, J., Poliziani, C., Rupi, F., Morgano, D., & Magi, M. (2021). Building a Large-Scale Micro-Simulation Transport Scenario Using Big Data. ISPRS International Journal of Geo-Information, 10(3), 165. https://doi.org/10.3390/ijgi10030165

Dian Khumara, M. A., Fauziyyah, L., & Kristalina, P. (2018). Estimation of Urban Traffic State Using Simulation of Urban Mobility(SUMO) to Optimize Intelligent Transport System in Smart City. 2018 International Electronics Symposium on Engineering Technology and Applications (IES-ETA), 163–169. doi:10.1109/ELECSYM.2018.8615508

Barrachina, J., Garrido, P., Fogue, M., Martinez, F. J., Cano, J.-C., Calafate, C. T., & Manzoni, P. (2014). Reducing emergency services arrival time by using vehicular communications and Evolution Strategies. Expert Systems with Applications, 41(4, Part 1), 1206–1217. doi:10.1016/j.eswa.2013.08.004

Benner, K. M., Feather, M. S., Johnson, W. L., & Zorman, L. A. (1993). Utilizing Scenarios in the Software Development Process. In N. Prakash, C. Rolland, & B. Pernici (Eds.), Information System Development Process (pp. 117–134). doi:10.1016/B978-0-444-81594-1.50013-1

Fontaras, G., Ciuffo, B., Tsiakmakis, S., Anagnostopoulos, K., Marotta, A., Pavlovic, J., … Zacharof, N. (01 2015). Simplified Technology-Specific Simulation Approach for Estimation of CO_2 Emissions from Traffic Simulation Models. doi:10.13140/RG.2.1.1793.4562

Strohmandl, J. (10 2015). Development of simulation model for light-controlled road junction in the program Technomatix Plant Simulation. doi:10.13140/RG.2.2.29892.63368

Ma, X., Huang, Z., & Koutsopoulos, H. (2014). Integrated Traffic and Emission Simulation: a Model Calibration Approach Using Aggregate Information. Environmental Modeling & Assessment, 19(4), 271–282. doi:10.1007/s10666-013-9397-8

Bieker-Walz, L., Krajzewicz, D., Morra, A., Michelacci, C., & Cartolano, F. (03 2015). Traffic Simulation for All: A Real World Traffic Scenario from the City of Bologna. Lecture Notes in Control and Information Sciences, 13, 47–60. doi:10.1007/978-3-319-15024-6_4

Vent, R. (2015). Real traffic flow modelling with SUMO.

Huang, B., Zhang, Y., Lu, L., & Lu, J. J. (2014). A new access density definition and its correlation with crash rates by microscopic traffic simulation method. Accident Analysis & Prevention, 64, 111–122. doi:10.1016/j.aap.2013.11.014

OpenStreetMap (2017, January 1). Planet dump retrieved from. OpenStreetMap Contributers. Retrieved January 1, 2023, from https://planet.osm.org", https://www.openstreetmap.org

Lopez, P. A., Behrisch, M., Bieker-Walz, L., Erdmann, J., Flötteröd, Y.-P., Hilbrich, R., … Wiessner, E. (2018). Microscopic Traffic Simulation using SUMO. 2018 21st International Conference on Intelligent Transportation Systems (ITSC), 2575–2582. doi:10.1109/ITSC.2018.8569938

Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı 48, S. 64-66, Şubat 2023
© Telif hakkı EJOSAT'a aittir
Araştırma Makalesi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue 48, pp. 64-66, February 2023
Copyright © 2023 EJOSAT
Research Article

Obtaining Pectin Reinforced Polyester Composite and Investigation of Thermophysical Properties

Mukaddes Karataş[1] and Ercan Aydoğmuş[1*]

[1]Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ, Türkiye, (ORCID: 0000-0001-5803-6821), mkozturk@firat.edu.tr
[1*]Fırat University, Faculty of Engineering, Department of Chemical Engineering, Elazığ, Türkiye, (ORCID: 0000-0002-1643-2487), ercanaydogmus@firat.edu.tr

(1st International Conference on Frontiers in Academic Research ICFAR 2023, February 18-21, 2023)

(**DOI:** 10.31590/ejosat.1254020)

ATIF/REFERENCE: Karataş, M., & Aydoğmuş, E. (2023). Obtaining Pectin Reinforced Polyester Composite and Investigation of Thermophysical Properties. *European Journal of Science and Technology*, (48), 40-44.

Abstract

In this study, pectin powder is mixed homogeneously in unsaturated polyester (UP). For the production of polyester composite, methyl ethyl ketone peroxide (MEKP) and cobalt octoate (Co Oc) are added to the mixture. The obtained composite is poured into standard molds as a gel and allowed to cure for 24 hours. Some physical and chemical properties of the composite are determined and characterization processes are carried out. Density, Shore D hardness, thermal conductivity coefficient, and thermal stability of polyester composite are examined. According to the results obtained, pectin is used as a filler in the polyester composite. There is no change in the chemical structure of the polyester polymer with Fourier transform infrared (FTIR) spectroscopy. The density of polyester composites decreases as the reinforcement of 0 wt.%, 1 wt.%, 3 wt.%, 5 wt.%, and 7 wt.% pectin powder increases. Besides, the reinforcement of pectin powder as filler reduces Shore D hardness of the polyester composite. However, it has been observed that the thermal conductivity coefficient of the polyester composite increases as the filler ratio rises. In thermal decomposition experiments of the composite, the activation energy decreases slightly as the filler ratio increases. According to the optimization results, 3 wt.% pectin powder supplementation does not adversely affect both the surface morphology and thermophysical properties of the polyester composite.

Keywords: Pectin powder, polyester composite, density, Shore D, activation energy.

Pektin Takviyeli Polyester Kompozit Elde Edilmesi ve Termofiziksel Özelliklerinin İncelenmesi

Öz

Bu çalışmada, pektin tozu doymamış polyester (UP) içinde homojen bir şekilde karıştırılmıştır. Polyester kompozit üretimi için karışıma metil etil keton peroksit (MEKP) ve kobalt oktoat (Co Oc) eklenir. Elde edilen kompozit standart kalıplara jel olarak dökülür ve 24 saat kürlenmeye bırakılır. Kompozitin bazı fiziksel ve kimyasal özellikleri belirlenir ve karakterizasyon işlemleri yapılır. Polyester kompozitin yoğunluğu, Shore D sertliği, termal iletkenlik katsayısı ve termal kararlılığı incelenir. Elde edilen sonuçlara göre polyester kompozitte dolgu maddesi olarak pektin kullanılmaktadır. Fourier dönüşümü kızılötesi (FTIR) spektroskopisi ile polyester polimerin kimyasal yapısında herhangi bir değişiklik olmamıştır. Polyester kompozitlerin yoğunluğu, ağırlıkça % 0, % 1, % 3, % 5 ve % 7 pektin tozu takviyesi arttıkça azalır. Ayrıca dolgu maddesi olarak pektin tozunun takviyesi, polyester kompozitin Shore D sertliğini azaltır. Ancak dolgu oranı arttıkça polyester kompozitin ısıl iletkenlik katsayısının arttığı gözlemlenmiştir. Kompozitin ısıl ayrışma deneylerinde dolgu oranı arttıkça aktivasyon enerjisi bir miktar azalmaktadır. Optimizasyon sonuçlarına göre ağırlıkça % 3 pektin tozu ilavesi polyester kompozitin hem yüzey morfolojisini hem de termofiziksel özelliklerini olumsuz etkilememiştir.

Anahtar Kelimeler: Pektin tozu, polyester kompozit, yoğunluk, Shore D, aktivasyon enerjisi.

1. Introduction

Composites based on polymers have become increasingly in demand because they are relatively inexpensive and offer excellent physicochemical properties in terms of thermal, mechanical, and moisture resistance. Natural fiber-reinforced polymer composites, which will not cause environmental problems after use due to their high biodegradability, are a class of sustainable materials that exhibit good mechanical properties for many applications [1-3].

Polysaccharides, the main component of biomass, are the most abundant renewable polymer sources in nature. Pectin, one of the most important among them, has potential uses in many industries. Pectin, which is composed mainly of galacturonic acid units, differs in composition, structure, and molecular weight, and is the most structurally and functionally complex polysaccharide found in plant cell walls [4-7]. Pectin, a homopolymer consisting mainly of galacturonic acid linked by α-1,4-glycosidic bonds, is used in the food industry, cosmetics and personal care products, and the pharmaceutical industry. There are studies in the literature on polyester composites reinforced with natural fibers [8-14].

Composite materials produced by using various fillers in recent years are becoming more common day by day. In particular, composites are strengthened with organic and inorganic reinforcing materials to improve them thermally and mechanically. For example, boron factory components (such as colemanite, ulexite, and tincal) are used to improve the thermophysical properties of polyester composite materials. Besides, as aerosil, alumina, Fe_3O_4, and microsphere reinforcement, it provides mechanical and thermal improvements to the polyester composite [15-23]. Nanoparticles such as graphene (GN), silicon carbide (SiC), and carbon nanotube (CNT) are also preferred in polyester composite production [24].

In studies in the literature, polymer wastes such as polyethylene terephthalate (PET), expanded polystyrene (EPS), mask, and polyurethane are used in polyester composites. Such polymer wastes are both recovered and used in the production of an economical composite material. Hence, the obtained polyester composite has been reinforced with polymer wastes that cause environmental pollution [25-28].

There are also studies in the literature on polyesters synthesized by obtaining raw materials from renewable sources. Both chemical and physical interactions can occur in polyester composites produced using modified palm and castor oil. As a filler, the leaves of some fibrous plants can be reinforced into the polyester composite. In the studies, low density, easy-to-process, economical, and environmentally friendly biocomposites are produced by using the leaves of *Asphodelus aestivus*, waste corncob, *Cornus alba*, and *Ficus elastic*. Optimum ratios should be determined in the production of biomass reinforced polyester composites. The addition of high biomass weakens both the surface morphology and mechanical properties of the composite. Composite materials with irregular pore structures are not preferred. Moreover, high biomass reinforcement weakens the thermal decomposition behavior of the polyester composite. The thermal stability of the composite is evaluated by calculating the activation energies found in the thermal degradation kinetics [29-35].

No report investigating the thermophysical properties of pectin-reinforced polyester composites has been found. This report aims to synthesize pectin reinforced polyester composites and determine their thermophysical properties such as density, hardness, and thermal conductivity to develop highly biodegradable composites with superior thermophysical properties. In this study, it is understood that polyester composite materials can be produced by reinforcing pectin powder. By using renewable resources (biomass), low-density, economical, and easy-to-process biocomposites are being improved. Also, environmentally friendly composites are produced by reducing the petrochemical composition and carbon footprint of the polyester composite.

2. Materials and Methods

The pectin powder used in this study is under 149 microns in particle size. The bulk density of pectin powder is determined as 0.113 g/cm^3.

Unsaturated polyester (UP), methyl ethyl ketone peroxide (MEKP), and cobalt octoate (Co Oc) used in the experiments are supplied by Turkuaz Polyester Company.

In this study, pectin powder is supplemented into UP and homogenization is provided for 5 minutes at a mixing speed of 750 rpm. Then, the chemical reaction is carried out by adding MEKP and Co Oc components to the mixture in certain proportions. The mixture obtained is mixed at 750 rpm for 2 minutes and then poured into standard molds. After waiting 24 hours for the obtained polyester composite to cure, necessary physical tests and chemical analyzes are performed [32,33].

In Figure 1, ground and dried pectin powders are prepared for polyester composite production.

Figure 1. Pectin powder

Figure 2 shows the production of the polyester composite and its cured form in the standard mold.

Figure 2. Polyester composite production scheme

In Table 1, UP, MEKP, and Co Oc components used in the experiments and their weight ratios are expressed.

Table 1. Composite production plan

UP (wt.%)	MEKP (wt.%)	Co Oc (wt.%)	Pectin (wt.%)
98.0	1.4	0.6	0
97.0	1.4	0.6	1
95.0	1.4	0.6	3
93.0	1.4	0.6	5
91.0	1.4	0.6	7

3. Results and Discussion

In this research, the density, Shore D hardness, thermal conductivity coefficient, and surface morphology of the produced polyester composite have been investigated. As seen in Figure 3, pectin powder supplementation slightly reduces the density of the polyester composite. In Figure 4, it has been determined that Shore D hardness of the polyester composite decreases with increasing filler content. However, pectin powder supplementation slightly raises the thermal conductivity coefficient of the produced polyester composite (Figure 5).

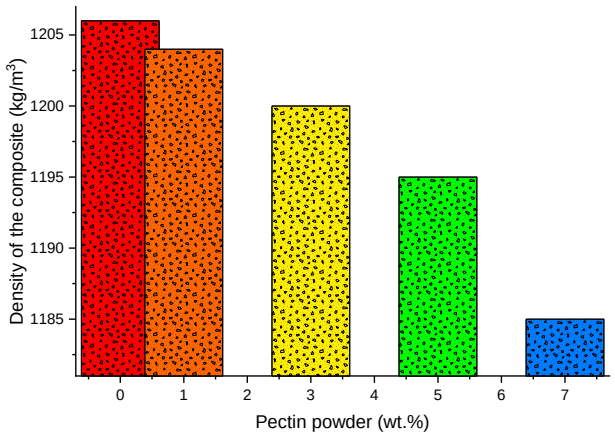


Figure 3. The effect of pectin reinforcement on the density of the composite

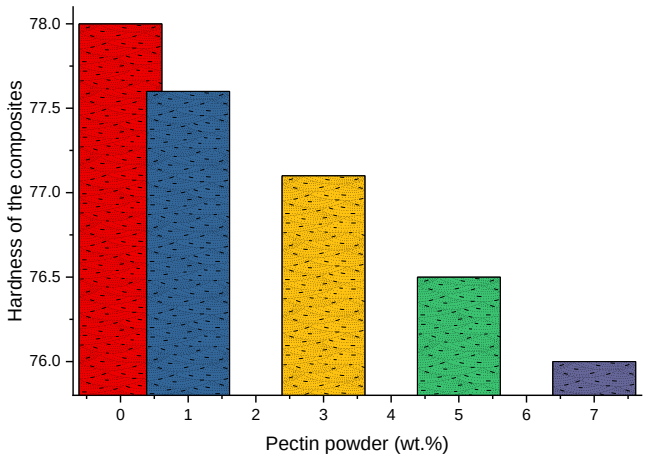


Figure 4. The effect of pectin reinforcement on the hardness of the composites

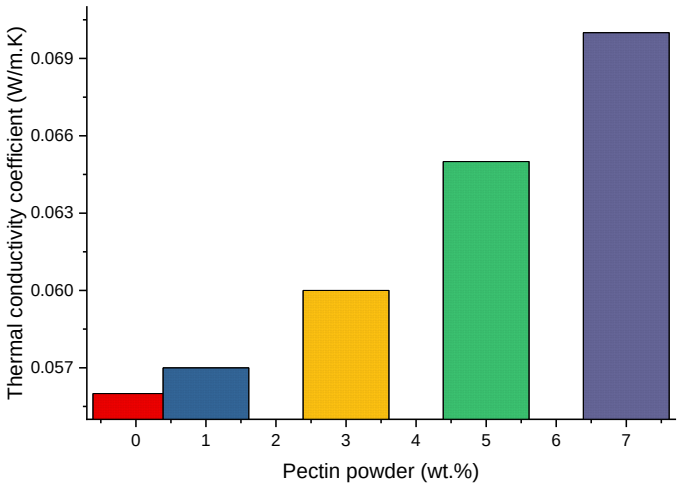


Figure 5. The effect of pectin reinforcement on the thermal conductivity of the composites

Table 2 provides activation energies calculated from thermal decomposition experiments of the polyester compositesIt has been determined that the activation energy of the produced composite decreases slightly as the pectin powder ratio in the mixture increases. Coats Redfern method has been used to calculate activation energy (*Ea*). The highest coefficient of determination is calculated by the three-dimensional diffusion equation. Activation energies of pectin reinforced the composites at a certain conversion ratio (range of 0.20 to 0.80) found. Thermal decomposition experiments have been carried out from 20 °C to 600 °C at a heating rate of 10 °C/min [34,35].

Table 2. Activation energies of the polyester composites

Filler ratios (wt.%)	Activation energy (*Ea*: kJ/mol)
0	121.56
1	118.79
3	115.68
5	112.93
7	109.85

In this study, 5 wt.% and higher pectin powder reinforcement negatively affect the surface morphology of the polyester composite. Figure 6 shows a scanning electron microscope (SEM) image of the pure polyester polymer. When pectin powder is reinforced as filler at optimum ratios (3 wt.%), both the pore structure and thermophysical properties of the polyester composite are not negatively affected.

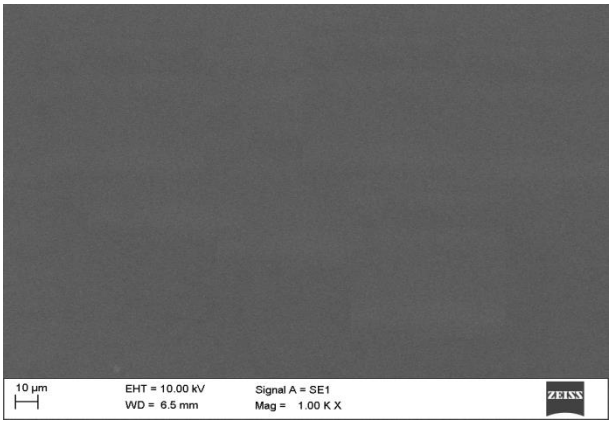


Figure 6. SEM image of pure polyester polymer

4. Conclusions and Recommendations

In this study, pectin powder is used as a reinforcing agent to produce an environmentally friendly polyester composite with low density and is easy to process. The use of such fillers improves some thermophysical properties of the composite. According to the results obtained, pectin supplementation slightly reduces the density and Shore D hardness of the polyester composite. However, a slight increase in the thermal conductivity coefficient of the composites occurs with the filler reinforcement. Reinforcing the pectin powder into the composite reduces the use of petrochemical raw materials and encourages the production of economical, easy-to-process, and environmentally friendly biocomposites.

References

[1] Shibata, M., Takachiyo, K.I., Ozawa, K., Yosomiya, R., and Takeishi, H. Biodegradable polyester composites reinforced with short abaca fiber, J Appl Polym Sci, 85, 129–138, 2002.

[2] Jagadeesh, P., Puttegowda, M., Girijappa, Y.G.T., Rangappa, S.M., and Siengchin S. Effect of natural filler materials on fiber reinforced hybrid polymer composites: An Overview, Journal of Natural Fibers, 19(11), 4132-4147, 2022.

[3] Bagherpour, S. Fibre Reinforced Polyester Composites, Intech, Rijeka, Croatia, 56-385, 2012.

[4] Nesic, A., Meseldzija, S., Cabrera-Barjas, G., and Onjia, A. Novel Biocomposite Films Based on High Methoxyl Pectin Reinforced with Zeolite Y for Food Packaging Applications, Foods, 11, 360, 2022.

[5] Valdés, A., Burgos, N., Jiménez, A., and Garrigós, M.C. Natural Pectin Polysaccharides as Edible Coatings, Coatings, 5(4), 865-886, 2015.

[6] Mohnen, D. Pectin structure and biosynthesis, Current Opinion in Plant Biology, 11(3), 266-277, 2008.

[7] Lara-Espinoza, C., Carvajal-Millán, E., Balandrán-Quintana, R., López-Franco, Y., and Rascón-Chu, A. Pectin and Pectin-Based Composite Materials: Beyond Food Texture, Molecules, 23(4), 942, 2018.

[8] Sriamornsak, P. Application of pectin in oral drug delivery, Expert Opinion on Drug Delivery, 8(8), 1009-1023, 2011.

[9] Marangoni Júnior, L., Fozzatti, C.R., Jamróz, E., Vieira R.P., and Alves, R.M.V. Biopolymer-Based Films from Sodium Alginate and Citrus Pectin Reinforced with SiO_2, Materials, 15(11), 3881, 2022.

[10] Picot-Allain, M.C.N., Ramasawmy, B., and Emmambux, M.N. Extraction, Characterisation, and Application of Pectin from Tropical and Sub-Tropical Fruits: A Review, Food Reviews International, 38(3), 282-312, 2022.

[11] Pothan, L.A., Oommen, Z., and Thomas, S. Dynamic mechanical analysis of banana fiber reinforced polyester composites, Compos Sci Technol, 63, 283–293, 2003.

[12] Baiardo, M., Zini, E., and Scandola, M. Flax fibre–polyester composites, Composites Part A: Applied Science and Manufacturing, 35(6), 703-710, 2004.

[13] Monteiro, S.N., Terrones, L.A.H., and D'Almeida, J.R.M. Mechanical performance of coir fiber/polyester composites, Polymer Testing, 27(5), 591-595, 2008.

[14] Senthilkumar, K., Rajini, N., Saba, N., and et al. Effect of Alkali Treatment on Mechanical and Morphological Properties of Pineapple Leaf Fibre/Polyester Composites, J Polym Environ, 27, 1191–1201, 2019.

[15] Dağ, M., Yanen, C., and Aydoğmuş, E. Effect of Boron Factory Components on Thermophysical Properties of Epoxy Composite, European Journal of Science and Technology, 36, 151–154, 2022.

[16] Orhan, R., Aydoğmuş, E., Topuz, S., and Arslanoğlu, H. Investigation of thermo-mechanical characteristics of borax reinforced polyester composites, Journal of Building Engineering, 42, 103051, 2021.

[17] Yanen, C., Dağ, M., and Aydoğmuş, E. Investigation of Thermophysical Properties of Colemanite, Ulexite, and Tincal Reinforced Polyester Composites, European Journal of Science and Technology, 36, 155–159, 2022.

[18] Yilmaz, E., Aydoğmuş, E., and Demir, A. Life Cycle Assessment and Characterization of Tincal Ore Reinforced Polyester and Vinylester Composites, Journal of the Turkish Chemical Society Section B: Chemical Engineering, 5(2), 183-194, 2022.

[19] Aydoğmuş, E., and Arslanoğlu, H. Kinetics of thermal decomposition of the polyester nanocomposites, Petroleum Science and Technology, 39(13–14), 484–500, 2021.

[20] Şahal, H., and Aydoğmuş, E. Investigation of Thermophysical Properties of Polyester Composites Produced with Synthesized MSG and Nano-Alumina, European Journal of Science and Technology, 34, 95-99, 2022.

[21] Şahal, H., Aydoğmuş, E., and Arslanoğlu, H. Investigation of thermophysical properties of synthesized SA and nano-alumina reinforced polyester composites, Petroleum Science and Technology, 1–17, 2022.

[22] Pekdemir, M. E., Aydoğmuş, E., and Arslanoğlu, H. (2023). Thermal decomposition kinetics of synthesized poly(N-isopropylacrylamide) and Fe_3O_4 coated nanocomposite: Evaluation of calculated activation energy by RSM. Petroleum Science and Technology, 1-19, 2023.

[23] Aydoğmuş, E., Aydın, M., and Arslanoğlu, H. Production and characterization of microsphere reinforced polyester composite: Modeling of thermal decomposition with ANN and optimization studies by RSM. Petroleum Science and Technology, 1-17, 2022.

[24] Yanen, C., and Aydoğmuş, E. Characterization of Thermo-Physical Properties of Nanoparticle Reinforced the Polyester Nanocomposite, Dicle University Journal of the Institute of Natural and Applied Science, 10(2), 121–132, 2021.

[25] Aydoğmuş, E., Arslanoğlu, H., and Dağ, M. Production of waste polyethylene terephthalate reinforced biocomposite with RSM design and evaluation of thermophysical properties by ANN, Journal of Building Engineering, 44, 103337, 2021.

[26] Aydoğmuş, E., Dağ, M., Yalçın, Z. G., and Arslanoğlu, H. Synthesis and characterization of EPS reinforced modified castor oil-based epoxy biocomposite, Journal of Building Engineering, 47, 103897, 2022.

[27] Demirel, M. H., and Aydoğmuş, E. Production and Characterization of Waste Mask Reinforced Polyester Composite, Journal of Inonu University Health Services Vocational School. 10(1), 41-49, 2022.

[28] Demirel, M. H., and Aydoğmuş, E. Waste Polyurethane Reinforced Polyester Composite, Production and Characterization, Journal of the Turkish Chemical Society Section A: Chemistry, 9(1), 443–452, 2022.

[29] Aydoğmuş, E. Biohybrid nanocomposite production and characterization by RSM investigation of thermal decomposition kinetics with ANN, Biomass Conversion and Biorefinery, 12, 4799-4816, 2022.

[30] Şahal, H., and Aydoğmuş, E. Production and Characterization of Palm Oil Based Epoxy Biocomposite by RSM Design, Hittite Journal of Science and Engineering, 8(4), 287-297, 2021.

[31] Aydoğmuş, E., Dağ, M., Yalçın, Z. G., and Arslanoğlu, H. Synthesis and characterization of waste polyethylene reinforced modified castor oil-based polyester biocomposite, Journal of Applied Polymer Science, 139, e525256, 2022.

[32] Orhan, R., and Aydoğmuş, E. Investigation of some thermophysical properties of *Asphodelus aestivus* reinforced polyester composite, Firat University Journal of Experimental and Computational Engineering 1(3), 103-109, 2022.

[33] Orhan, R., and Aydoğmuş, E. Production and Characterization of Waste Corncob Reinforced Polyester Composite, European Journal of Science and Technology Special Issue. 42, 176-179, 2022.

[34] Buran, A., Durğun, M. E., and Aydoğmuş, E. *Cornus alba* Reinforced Polyester-Epoxy Hybrid Composite Production and Characterization, European Journal of Science and Technology, 43, 99-103, 2022.

[35] Buran, A., Durğun, M. E., Aydoğmuş, E., and Arslanoğlu, H. Determination of thermophysical properties of *Ficus elastica* leaves reinforced epoxy composite, Firat University Journal of Experimental and Computational Engineering, 2(1), 12-22, 2023.