Journal of Soft Computing and Artificial Intelligence

ISSN: 2717-8226

Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

June, 2023

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Crossref (Doi beginning: 10.55195/jscai..xxxxxx)

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Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Review Article

Internet of Senses Potential Applications and Implications

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ARTICLE INFO

Article history:
Received June 19, 2023
Revised September 12, 2023
Accepted November 4, 2023

Keywords:
Internet of Senses
Near Future Technology
Usage areas of IoS
IoT

ABSTRACT

The Internet of Senses (IoS) is an emerging field that aims to enhance human-machine interaction by enabling individuals to experience the digital world with their senses. This article, which explores a highly novel research topic, is at the forefront of Ericsson engineers' investigations, providing pioneering insights into the subject matter. IoS employs technologies such as virtual and augmented reality, haptic feedback, and olfactory and gustatory systems to provide multi-sensory experiences. This article provides an overview of the latest trends and innovations in IoS, highlighting its potential for human well-being and progress as well as the challenges that need to be addressed to ensure its safe and ethical implementation. The article also emphasizes the role of 6G in enabling IoS and the potential benefits of incorporating the chemical senses into digital technology. Overall, the IoS has the potential to revolutionize human-machine interaction and create immersive digital experiences.

1. Introduction

The IoS is a concept that represents a futuristic vision of a world where humans and machines are seamlessly connected, creating a new level of interaction between people and their environment. The idea behind this concept is that our senses are our primary means of experiencing the world around us, and technology can enhance and extend these senses beyond their natural limitations. With the IoS, individuals can have digital sensory experiences that closely resemble real-life experiences, creating a more immersive and sensory-rich world. The IoS integrates various technologies, including visual, audio, haptic, and others, to extend human senses beyond the limitations of our physical bodies. This innovation allows for heightened senses of vision, hearing, touch, and even smell, providing a new way for people to interact with digital content. Imagine being able to feel the texture of a fabric or the temperature of a surface through a screen, or even smell the aroma of a dish being prepared on the other side of the world.[1] The IoS has the potential to revolutionize the way we interact with technology and each other. However, with this level of connectivity comes new challenges and ethical considerations that must be addressed to ensure the safety and privacy of individuals. As we move towards a more interconnected world, we must ensure that the data being collected through these technologies is protected and used ethically. Moreover, the seamless integration of our senses with technology also raises questions about the impact on our physical and mental well-being. It is crucial to consider the potential consequences of this level of connectivity and address them before fully implementing the IoS. The future of the IoS is interdependent with the Metaverse, a virtual world where users can interact with each other and digital objects in a fully immersive way [2]. The relationship between these technologies is symbiotic, with each one augmenting the capabilities of the other.

The introduction of 6G as a connecting link

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DOI: 10.55195/jscai.1404604

facilitates the creation of immersive digital experiences that seamlessly integrate multiple sensory modalities. With the IoS, we can create a fully immersive, multisensory environment that revolutionizes our digital experiences [2].

Technology has significantly aided the conversion of our senses into digital formats, equipping us with instruments to record, scrutinize, and recreate stimuli from our surroundings. This capability empowers both people and machines to recognize and react to these stimuli. However, current devices primarily rely on audiovisual media and lack the ability to capture and stimulate the senses of smell, taste, and touch. To achieve a complete convergence of the physical and digital worlds, which is expected to be the next stage of the Internet, technology needs to cater to the chemical senses and associated stimuli.

2. Potential of the IoS and the Future of 6G Networks

The olfaction and perfume industries have significant potential, as highlighted in a recent report by MIT, which indicates that the global perfume industry currently generates a staggering $71 billion in revenue. [1,2] Hence, it is imperative that the development of new technologies include the ability to capture and simulate the chemical senses, thereby enhancing the user experience and expanding the possibilities of digital technology. [1,2]

Designers and developers may find value in research that explores the potential for touch, taste, and smell in human-computer interaction. This research introduces new ways of discussing taste and related experiences, and it could provide opportunities for more meaningful use of these senses. Often, people describe their experiences with taste using simple terms such as "I like it" or "it's sweet," but these descriptions do not convey the underlying properties of the experience, which can be important for designers to understand. By developing a framework that includes more detailed descriptions, such as "it is lingering," designers can create a more nuanced vocabulary and facilitate interesting discussions about interaction design. [1,2]

The upcoming 6G networks are expected to provide a significant boost to various areas. The design of 6G is centered around four main use cases, namely: connected intelligent machines, a digitized and programmable world, a connected sustainable world, and the IoS. The IoS is a concept that involves providing multisensory experiences that are almost indistinguishable from reality by using visual, auditory, haptic, olfactory, and gustatory stimuli. This is aimed at enhancing human-machine interaction and improving the overall experience.

The term IoS was coined by Ericsson, and it aims to provide immersive experiences that are almost indistinguishable from reality while increasing the interaction between humans and machines. This is achieved by using visual, auditory, haptic, olfactory, and gustatory stimuli in virtual and augmented experiences [3].

Ericsson (2016) suggests that the IoS may emerge by 2030, enabling direct access to the Internet space through the interface provided by our brains.[3] While this vision may seem utopian, it is possible that IoT devices will evolve into the IoS, which would allow humans to sense the world through a digital sixth sense that complements the traditional five senses. ZTE Corporation (2020) presents a more practical perspective on IoS as a pervasive technology that could be enabled by future 6G networks.[4]

The IoS has become a key area of interest for the development of future 6G technology, with major telecommunications companies such as Ericsson and ZTE Corporation exploring its potential [3, 4]. However, the realization of an IoS-enabled scenario will require significant advancements in global communication networks, including the ability to handle increased traffic and provide massive data capacity.

3. IoT And 6G/7G

The network services are scheduled for an upgrade, moving from 6G to 7G, which will introduce improvements to our way of life and the automation of daily tasks through IoT.[5] The energy spectrum utilized by 6G surpasses that of 5G. While 6G is considered satisfactory for securing smart homes, it may not fully address the security and privacy concerns. Moreover, there is a growing demand for 6G/7G devices in healthcare, particularly for network-enabled medical gadgets, as they offer various applications in the healthcare sector. [6] Figure 1 depicts the evolution of cellular communication, illustrating the increase in our internet speed and the significant leap with the future emergence of 6G and 7G.

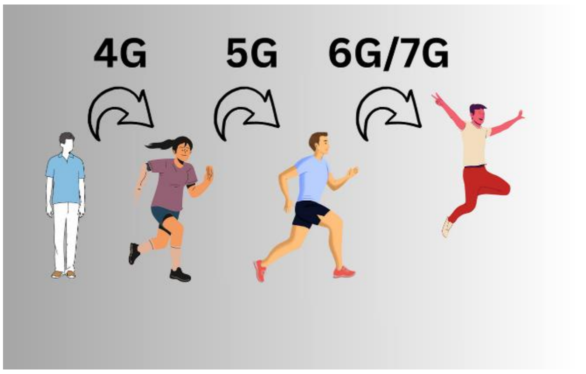

Figure 1 Evolution of Internet

In the realm of IoT-enabled smart transportation, the integration of connected cars and smart sensors embedded in bridges presents novel solutions to address daily challenges such as heavy traffic and limited parking space.[7] The integration of mobile edge networks in IoT-enabled smart devices is revolutionizing connectivity by providing enhanced access to AI, SDN, and IoT capabilities. The upcoming 6G network, slated for launch by 2030, is set to capitalize on advanced sensor technologies embedded within smart products [8].

This technological advancement has paved the way for a range of innovative devices, including smart refrigerators, washing machines, televisions, and other household appliances, as well as wearable gadgets like smart shoes and phones. However, it is imperative to prioritize addressing the security concerns associated with IoT-enabled applications to safeguard user safety and protect sensitive data [9].

Numerous IoT deployments encounter unique security challenges [10]. It is essential to address these hurdles in terahertz communication and prioritize the security of IoT products and services. The security aspects of IoT are addressed by the advancements brought forth by 6G/7G technologies.[11] The terahertz communication frequency band, ranging from 100 GHz to 10 THz, is being utilized in the era of 6G to 7G. This previously untapped frequency range offers limitless possibilities without any inherent limitations [12].

4. Mobile Communication Systems of 6G&7G

4.1. Communication Systems of 6G

The future 6G mobile system, designed for worldwide coverage, will incorporate both the existing 5G wireless mobile system and a satellite network. This satellite network comprises three key components: a telecommunication satellite network, an Earth imaging satellite network, and a navigation satellite network. The telecommunication satellite network will be responsible for voice, data, internet, and video broadcasting services, while the Earth imaging satellite network will focus on collecting weather and environmental information. Lastly, the navigation satellite network will enable the Global Positioning System (GPS) functionality. These satellite systems have been independently developed by different countries. The United States is responsible for the creation of the GPS, China has developed the COMPASS system, the European Union has introduced the Galileo system, and Russia has developed the GLONASS system.[13] As evidenced in Table 1, each successive generation of cellular technology, ranging from 4G to the emerging 7G, exhibits significant advancements in frequency bands, services offered, data rates, and other specific characteristics, highlighting the ongoing evolution of mobile communication technologies.

Table 1 Each generation of cellular technology, from 4G to 7G, advancements in Frequency, Services, Data Rates, and other specific information [14].

Parameters	Cellular Technologies			
	4G	5G	6G	7G
Frequency	2GHz-8 GHz	4G Frequency	95GHz-3THz	95GHz-3THz
Service	Wi-Fi, VoIP, LTE, WiMAX	Worldwide Wireless Web	Secured And Global Cellular Services	Secured And Global Cellular Services
Multiplexing	Orthogonal Frequency Division Multiple Access	All With AI Capabilities, Multiple Input Multiple Output, Code Division Multiple Access	Code Division Multiple Access	Code Division Multiple Access
Switching Type	Packet Switching (All Packer)	Ipv6 But Advancements Are Still To Be Done	All Packet	All Packet
Core Network	Internet	Internet	Internet	Internet
Data Rate	100-300 Mbps	About 100+Mbps	About 11 Gbps	About 11+Gbps
Advantages	Speed, High Speed Hand Offs, MIMO Tech, Global Tech	Better Coverage Area, Low Battery Consumption, Availability of Multiple Data Transfer Path, Energy and Spectral Efficiency Is More and Has a High Security	Global Coverage System	No Issue of Data Capacity Coverage and Low Cost of Call
Disadvantages	Hard To Implement, Complicated Hardware Required	The process and research on its viability are still ongoing. Achieving it is challenging due to inadequate technological support in many parts of the world. Developing the necessary infrastructure is costly, and security and privacy concerns remain unresolved.	Difficulty For Space Roaming, High Cost of Mobile Call and Similar With 5G Disadvantages	Similar With 5G And 6G Disadvantages
Location Of First Commercialization	South Korea	South Korea	Not Yet	Not Yet

4.2. Communication Systems of 7G

The 6G and 7G mobile network aims to provide global coverage while incorporating satellite functionality for mobile communication. [Table1] Within the satellite system, telecommunication satellites will facilitate voice and multimedia communication, navigational satellites will enable global positioning systems (GPS), and earth imaging satellites will provide additional information such as weather updates [13]. The 6G mobile wireless network will support local voice coverage and various services. However, the realization of 7G poses certain challenges that require further research, including seamless mobile phone usage during transitions between countries, considering that satellites also move at constant speeds within specific orbits. Additionally, standards and protocols need to be established for cellular-to-satellite and satellite-to-satellite communication systems. The ultimate realization of 7G can only be achieved once all these standards and protocols are defined. It is possible that these advancements may be realized in subsequent generations beyond 7G, potentially referred to as 7.5G.

5. IoS Definition

The IoS has emerged as a new frontier in the realm of human-machine interaction, focusing on the sensory aspects of sight, smell, mind, taste, touch, and sound. [Figure2] It refers to a concept where people can experience the digital world with their senses, using technologies like virtual and augmented reality, haptic feedback, and olfactory and gustatory systems. IoS promises to blur the boundaries between the physical and digital worlds, offering new possibilities for communication, entertainment, and education.

In recent years, IoS has witnessed significant developments, driven by advances in sensor technologies, data processing, and artificial intelligence. However, the reliability of IoT is a concern, and there are problems in the process of utilizing it [15]. Therefore, more research is needed to explore the potential of the IoS and IoT in different areas, including social interaction, healthcare, and environmental monitoring.

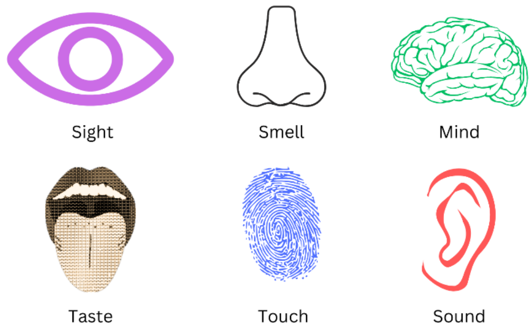

Figure 2 Senses of Body

6. Usage Areas on The Senses

The IoS has the potential to revolutionize the way we live, work, and interact with the world around us. Here are some of the potential applications and implications:

- Enhanced entertainment and media experiences: The IoS can create immersive and interactive entertainment experiences, such as virtual concerts, gaming, and movies.
- Improved healthcare and wellbeing: The IoS can improve healthcare outcomes by enabling remote monitoring, diagnosis, and treatment of patients, as well as enhancing the quality of life for people with disabilities and sensory impairments.
- Enhanced learning and education: The IoS can create personalized, and immersive learning experiences that stimulate multiple senses, making it easier for students to retain information and learn complex concepts.
- Increased productivity and efficiency: The IoS can enhance productivity and efficiency by providing real-time feedback and insights that help workers make better decisions and perform tasks more efficiently.
- Ethical and social implications: The IoS raises important ethical and social implications, such as privacy concerns, the potential for addiction and overstimulation, and the possibility of creating a society that is too reliant on technology.

6.1. Touch-Enabled Internet

The tactile internet refers to the ability to remotely access, monitor, and control objects or processes with haptic feedback, all in real-time [16]. A prime example of this technology is remote surgery, where haptic and audiovisual signals are transmitted from a remote location to a surgeon. With the use of immersive 3D HTC or XR video streaming techniques, the surgeon can interact with holograms or wear head-mounted VR glasses to receive audiovisual monitoring. The tactile internet has been extensively researched and is a compelling use case for the IoS, which aims to transform digital experiences into fully immersive, multisensory ones.

6.2. Trackable Personal Health

In the realm of the IoS, healthcare is an area that could greatly benefit from the use of connected sensors. By placing sensors on a patient's body, healthcare providers can remotely monitor vital health parameters such as blood pressure and heart rate. These sensors can be part of a larger sensor network, allowing for remote monitoring and timely intervention in emergency situations. Figure 3 seamlessly brings together the patient tracking system and Digital Senses under the IoS framework, creating an illustrative image for healthcare monitoring and management. Additionally, patient medical history can be recorded and stored for easy retrieval and use. Once these sensor networks are connected to the internet, medical professionals from around the world can collaborate and make real time decisions regarding critical health cases [17,18].

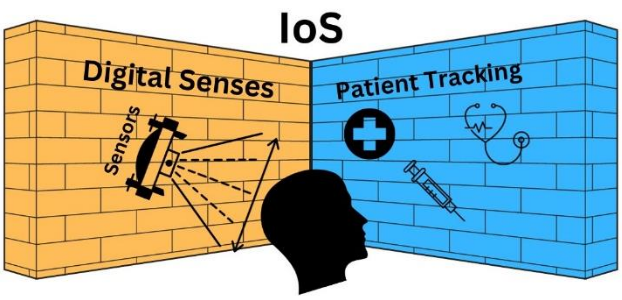

Figure 3 IoS for Patient Tracking

6.3. Education with Senses

The IoS has the implicit to revise the education sector. IoS is an arising technology that enables commerce between the real and virtual worlds by integrating the mortal senses into digital systems. By bedding detectors in objects and integrating pall computing, stoked reality, wearable technologies, and big data, different parameters of the educational terrain can be measured and anatomized to give useful information [19]. IoS can be used to enhance the quality of higher education by providing a more interactive and personalized learning experience, where students can engage with the course material using multiple senses. Therefore, more research is needed to explore the potential of IoS in education and to develop models and criteria for its implementation.

6.4. Smart Manufacturing

Smart manufacturing empowers factory managers to collect and analyze data automatically, leading to better-informed decisions and optimized production processes. This strategy revolves around the gathering and utilization of data, which offers insights into "what to do" and "when to do it". The use of IoS technology in smart manufacturing enables real-time monitoring and remote management of processes, leading to improved outcomes such as reduced waste, faster production, and better-quality goods. This technology facilitates the smooth flow of data from sensors and machines to the Cloud, where it is analyzed and combined with contextual information before being shared with authorized stakeholders. The adoption of IoS technology in manufacturing is expected to continue growing in the future, leading to even greater improvements in production processes and outcomes [20].

7. Ethics of IoS

The implementation and deployment of an "ethical" framing in IoT devices or services may come at an additional cost, but it can lead to a higher level of individual freedom and choice. This added value justifies the extra expense and is likely to attract users who prioritize ethical considerations, potentially creating a specific market for such products [21]. It appears that the aforementioned situation in the IoT will persist in future technologies such as the IoS, given the increasing prominence of ethical concerns and the growing importance placed on them by users. When considering how a standard such as this intersects with those whose data is at stake, challenges arise. The common solution is to use an "end user license agreement" (EULA), which specifies the details of the agreement. However, there are two immediate problems with EULAs. Firstly, they tend to be excessively detailed and filled with technical and legal jargon, making them difficult to comprehend for many users. Secondly, the length and density of these documents often result in users not reading them and simply clicking through to make them disappear [22]. To prevent the occurrence of such situations, there is a need for further research on the ethics and applications of the IoS, in a more comprehensive manner.

8. Conclusion

The findings of this review suggest that further research is needed to fully understand the potential benefits and limitations of the interventions discussed. The IoS represents a futuristic vision that has the potential to revolutionize the way we interact with technology and each other. This innovation integrates various technologies, including visual, audio, haptic, and chemical, to extend human senses beyond the limitations of our physical bodies. With the ability to provide multisensory experiences that are almost indistinguishable from reality, The IoS strives to elevate the interaction between humans and machines, with the goal of enhancing the overall user experience. However, to ensure the safety and privacy of individuals, new challenges and ethical considerations must be addressed as we move towards a more interconnected world. Moreover, it is crucial to consider the potential consequences of this level of connectivity and address them before fully implementing the IoS. The development of new technologies that include the ability to capture and simulate the chemical senses will enhance the user experience and expand the possibilities of digital technology. Advanced technology networks, including 6G and beyonds are expected to provide a significant boost to various areas, including the IoS, but their realization will require significant advancements in global communication networks, including the ability to handle increased traffic and provide massive data capacity. Overall, the IoS represents an exciting. Opportunity for designers, developers, and researchers to explore new ways of discussing taste and related experiences and facilitate interesting discussions about interaction design. It is important to note that the IoS is a highly innovative and nascent field, which is why the research in this area is still limited. Given its novelty, there is a significant scope for further exploration and investigation to fully comprehend and unlock the potential of this cutting-edge technology in transforming our sensory experiences and shaping the future of human-machine interaction.

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Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Research Article

Machine Learning Based a Comparative Analysis for Detecting Tweets of Earthquake Victims Asking for Help in the 2023 Turkey-Syria Earthquake

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ARTICLE INFO

Article history:
Received **September 24, 2023**
Revised **October 18, 2023**
Accepted **November 4, 2023**

Keywords:
Earthquake
Machine learning
Random forest
Sentiment analysis

ABSTRACT

Two major earthquakes in Kahramanmaraş on February 6, 2023, 9 hours apart, affected many countries, especially Turkey and Syria. It caused the death and injury of thousands of people. Earthquake survivors shared their help on social media after the earthquake. While people under the rubble shared some posts, some were for living materials. There were also posts unrelated to the earthquake. It is essential to analyze social media shares to manage the process effectively, save time, and reach the victims as soon as possible. In this study, about 500 tweets about the 2023 Turkey-Syria earthquake were analyzed. The tweets were classified according to their content as user tweets under debris and user tweets requesting life material. Popular machine learning methods such as DT, kNN, LR, NB, RF, SVM, and XGBoost were compared in detail. Experimental results showed that RF has over 99% classification accuracy.

1. Introduction

People have expressed their thoughts and experiences using different tools throughout their lives. Today, depending on the development of internet technologies, the use of social media is increasing, and sharing is done through social media [1]. Therefore, social media has become a powerful tool that directs events rather than just a communication tool. Sharing on social networks, an effective way of sharing thoughts is increasing daily and creates information stacks [2]. However, various methods are needed to process this information and make the data meaningful. Sentiment analysis comes to the fore to analyze and classify shared feelings, thoughts, and opinions. Sentiment analysis is a classification problem in which each share in the dataset is represented in different categories according to its content. Sentiment analysis is a text processing process that aims to determine the emotion expressed in the text [3].

Social media is a powerful communication tool. Especially when communication networks such as earthquakes are damaged, the use of social networks becomes more prominent [4]. Earthquake victims share their help needs on social media. In addition to the tweets posted by earthquake victims who need help, there are also tweets posted by malicious people. In addition, it is necessary to separate the tweets of the people under the rubble and the tweets that demand life materials. For this reason, analyzing tweets using artificial intelligence methods will be effective in terms of time and process management [5-6].

2023 Turkey-Syria earthquakes occurred on February 6, 2023, in the Pazarcık and Ekinözü districts of Kahramanmaraş, nine hours apart. The size of the earthquakes was announced as 7.8 MW and 7.5 MW [7]. As a result of earthquakes, approximately 50,000 people in Turkey and about 10,000 people in Syria were killed, and more than 129 thousand people were injured. After the

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earthquakes, nearly 17 thousand aftershocks reached up to 6.7 MW. The first earthquake was felt in a large area, including Turkey and Syria, as well as Cyprus, Egypt, Iran, Iraq, Israel, Jordan and Lebanon. The two major earthquakes have caused damage to approximately 350,000 km2 and affected 14 million people, which comprised 16% of Turkey's population.

Studies on analyzing posts shared through online social networks about various disasters, especially earthquakes, are remarkable in the literature. For example, sentiment analysis was used to predict the perspective of the society by analyzing the tweets, or many studies were conducted to understand whether the tweets were a call for help.

Mendon et al. [8] used various data pre-processing techniques. They proposed a hybrid model to analyze the sentiment of 243,746 posts shared on Twitter after the Kerelas natural disaster in India in 2018. Their study used TF-IDF, K-means, LDA, and Doc2Vec techniques.

Behl et al. [9] categorized earthquake-related datasets in Italy, Nepal, and the Covid-19 pandemic with supervised learning techniques. In these studies, a Multilayer Perceptron (MLP) model was proposed for classifying Twitter posts. It is compared with popular machine learning and deep learning methods. They tried categorizing tweets as 'resource availability,' 'resource needs, and 'others.'

Another study tried to understand whether the tweets about any emergency were analyzed and whether they were available or needed. This study proposed a hybrid deep learning model consisting of LSTM and CNN models. This model also aims to categorize non-English posts [10].

They proposed a deep learning-based model that analyzes the images obtained from smart infrastructures to support the solution to the problem of healthy disaster management and directing the available resources to the disaster areas in need at the right time. Deep learning models have shown higher accuracy than machine learning models [11].

Wang et al. [12] proposed a model for detecting rumors about disasters in social networks. In this study, 3793 content collected from Sina Weibo, a social networking platform, was analyzed. Various natural language processing techniques were used for sentiment analysis, and Support Vector Machines (SVM), Logistic Regression (LR), Random Forest (RF) and Extreme Gradient Boosting (XGBoost) models were used for rumor detection. As a result of the study, a robust model for rumor detection is proposed.

Ruz et al. [13] conducted sentiment analysis using two Twitter datasets related to the Chilean earthquake in 2010 and the 2017 Catalan independence referendum in 2017. They proposed a Bayesian network classifier and compared it with SVM and RF models. Their proposed model achieved successful results.

It is crucial to utilize instant information flow to strengthen the management processes of various disasters. Kryvasheyeu et al. [14] proposed a sensor method to analyze the sentiment of 50 million tweets sent before, during, and after Hurricane Sandy.

Huang et al. [15] proposed a text dynamic clustering-based method for early detection of events such as natural disasters, health, and social security emergencies using social media posts. They obtained very successful results with the BERT-Att-BiLSTM model.

Kumar et al. [16] proposed a multi-channel convolutional neural network (MCNN) model to classify tweets about disasters into eyewitness, non-eyewitness, and do not know classes. In doing so, they used a separate word embedding vector with this model. Their model gave the best results compared to popular deep learning and machine learning methods.

As seen in the literature, after disasters such as floods, hurricanes, and earthquakes that affect large regions and cause significant damage, early and correct intervention in the affected regions is crucial in crisis management. Many studies have been conducted in this domain, and different models have been proposed. Unlike traditional methods, advanced models are created thanks to the data obtained from social networks. In this study, tweets from the Turkey-Syria earthquake, which affected a large region and caused great destruction, were analyzed, and aid requests were classified. Here, it is aimed to reach users who need help quickly by utilizing the power of social networks.

In this study, machine learning methods such as Decision Tree (DT), LR, k-Nearest Neighbor (kNN), Naive Bayes (NB), RF, XGBoost and SVM are used to classify tweets posted after the earthquake in Kahramanmaraş, Turkey in February 2023. The used machine learning methods are used to classify tweets to identify users asking for help and relief supplies. Various metrics are used in the literature to compare machine learning methods [17-18]. In this study, F-score, precision, accuracy, and recall metrics were used. Experimental results showed that machine learning models successfully detected people seeking help and relief materials during the earthquake.

2. Material and Method

In this study, it was aimed to develop a model for earthquake combat, rescue, and aid efforts. It is classifying user tweets according to their content aimed at developing a model that could support search and rescue efforts and reach needy areas. For this purpose, a comparative analysis based on popular machine learning methods such as DT, kNN, LR, NB, RF, SVM, and XGBoost is presented.

2.1. Dataset

This study used a dataset consisting of 499 tweets about the 2023 Turkey-Syria earthquake. The tweets in the dataset consist of two classes. Class 1 consists of 299 tweets sent by earthquake victims seeking help. Out of 200 tweets, Class 0 has 150 tweets with keywords like "earthquake," "meal," and "blanket," and 50 tweets with no reference to the earthquake. The dataset used is publicly available on Kaggle via [19]. A sample representation of the dataset is shown in Table 1.

Table 1 A sample from the dataset

Text	Label
Kahramanmaraş türkoğlu ilçesi şekeroba köyü ça...	1
Teyitli, ses var, köpekler tepki veriyor. Her...	1
0539 693 27 99 bu arkadaş Kahramanmaraş'ta çad...	1
Babamın yaşadığı yere henüz yardım ulaşmamış ş...	1
Samsun Atakum'da 18 adet yeni eşyalı daire var	1

The top 50 words in tweets belonging to class 0 are shown in Figure 1.

Figure 1 The top 50 words in tweets belonging to class 0

Figure 2 shows the 50 most frequently mentioned words in tweets of class 1 sent by earthquake victims asking for help.

Figure 2 The top 50 words in tweets belonging to class 1

2.2. Data Pre-Processing

This study aimed to determine the tweets of the earthquake victims asking for help by analyzing the tweets shared about the 2023 Turkey-Syria earthquake. For this purpose, a comparative analysis based on popular machine learning methods such as DT, kNN, LR, NB, RF, SVM, and XGBoost is presented.

In natural language processing projects, text pre-processing is critical to ensure data can be processed correctly. Data pre-processing steps include cleaning, standardizing, and normalizing the data. In the data pre-processing phase, tokenization was performed first. Tokenization is the practice of breaking the raw text into small pieces. In the text normalization phase, spaces and accents were removed, uppercase letters were converted to lowercase, special characters and emoji were removed, numbers expressed in the text were converted to numbers, abbreviations were converted to their explicit form, and misspellings were corrected. Stemming and lemmatization followed. Stemming is the removal of affixes from each word in a text. Lemmatization is the morphological analysis of words to get to the word's root. Then, stop words that have no significance in the text were removed. Bag of words was used for feature extraction from the text. Bag of words is one of the methods for converting text into vectors. After preparing the matrix, the TF-IDF method was applied to statistically express the importance of a term in the document to weigh the terms in the text. Parameter analysis ensured that all machine learning algorithms applied in this study gave the most successful results. The parameters with the highest accuracy value were selected for each model. The parameters used for DT are criterion: gini and max_depth: 8. The k value determined for kNN is 15. For LR, C: 1.0 and penalty: l1. For RF, max_depth: 20 and n_estimators: 100. For SVM, gamma: 0.0001, C: 0.1 and kernel: rbf. For XGB, min_child_weight: 5 and max_depth: 5. Cross-validation was used to solve the overfitting problem. Cross-validation was done by choosing the k value as 10.

2.3. Baseline Models

Machine learning methods used in this study are briefly explained in this section.

DT: There are several methods in the literature that use tree structure [20]. DT is among the most preferred methods because the rule structure created is simple and understandable. This method aims to create a systematic tree structure to classify available data [21]. DT is carried out by first training the model with known examples and classifying different examples using the trained model [22].

kNN: This method is one of the most well-known, easy, and fast to implement among machine learning algorithms. This method makes classification using the closeness between a selected feature and the closest feature. The k samples in the closest distance from the data set to the new sample to be classified are looked at. Whichever class the k samples are in more often; the new sample is included in that class [23].

LR: LR is a statistical model that models the relationship of a dependent variable with one or more independent variables [24]. LR uses the sigmoid function to model the probability distribution of the dependent variable. The sigmoid function produces an output of either 0 or 1. The output produced expresses the probability of an event occurring [25].

NB: Naive Bayes algorithm, which is preferred for text classification because it is fast and easy to apply, is one of the machine learning methods that perform classification with a probabilistic approach. Assuming that each attribute in the dataset is independent of the other, it calculates the probability of indicating which class each belongs to and is based on Bayes' theorem [26-27].

RF: RF is an ensemble learning method based on decision trees [28]. Decision trees analyze the classes of training data and determine which class the test data belongs to base on rules extracted from the training data. These rules consist of a large number of if-then conditions [29].

SVM: One of the statistical learning techniques is called SVM, which is essentially a linear classifier for differentiating between two classes. The main purpose of SVM is to define the optimal decision function that separates the two classes. The optimal decision function is created by maximizing the distance between the support vectors and the points closest to them. SVM was later generalized for multi-class and non-linear data using a kernel function [30].

XGBoost: It is an ensemble tree algorithm developed by Chen and Guestrin [31]. XGBoost uses the gradient boosting algorithm. XGBoost is a model that combines decision trees to create a unified model with successful predictive performance. The inclusion of normalization in the objective function is used to reduce model complexity, reduce overfitting, and speed up the learning process. It minimizes cost, reduces overfitting, and improves the performance of model generalization. XGBoost is fast to interpret and can handle large datasets well [32].

2.4. Evaluation Metrics

Classification algorithms use labeled training datasets to make predictions. Precision, accuracy, recall, and F-score metrics are used to evaluate the performance of classification algorithms. These metrics are calculated using the Confusion Matrix (CM) seen in Table 2.

Table 2 The CM

		Real	
Predicted		Label 0	Label 1
	Label 0	TP	FP
	Label 1	FN	TN

As seen in Table 2, the CM consists of False Positive (FP), True Positive (TP), False Negative (FN), and True Negative (TN) values. TN refers to the number of samples classified as positive that are actually positive. FN refers to the number of samples whose actual label is positive but is classified as negative. FN refers to the number of samples whose actual label is negative but is classified as positive. TN refers to the number of samples classified as negative that are actually negative. Accuracy is defined as the count of correctly classified samples and is calculated using Eq. 1.

$$Accuracy = \frac{TP+TN}{TP+FP+FN+TN} \quad (1)$$

Precision expresses how many of the samples predicted as positive are actually positive and is calculated using Eq. 2.

$$Precision = \frac{TP}{TP+FP} \quad (2)$$

Recall, calculated by Eq. 3, calculates the proportion of correctly predicted positive examples among all positive examples.

$$Recall = \frac{TP}{TP+FN} \quad (3)$$

The F score, calculated by Eq. 4, represents a measure of test accuracy and is calculated as the harmonic mean of precision and recall.

$$F - score = \frac{2*Precision*Recall}{Precision+Recall} \quad (4)$$

3. The Experimental Results

In this study, a comparative analysis of kNN, DT, LR, NB, RF, SVM, and XGBoost algorithms were presented. Experimental results were obtained for each algorithm according to precision, accuracy, recall, and F-score metrics.

The CM of DT is shown in Table 3.

Table 3 DT's CM

		Real	
Predicted		Label 0	Label 1
	Label 0	56	5
	Label 1	1	88

As seen in Table 3, DT correctly classified 134 tweets and incorrectly classified 16 tweets. For DT, TP is 56, FP is 5, FN is 1, and TN is 88.

The CM of kNN is shown in Table 4.

Table 4 kNN's CM

		Real	
Predicted		Label 0	Label 1
	Label 0	48	6
	Label 1	9	87

As seen in Table 4, kNN correctly classified 134 tweets and incorrectly classified 16 tweets. For kNN, TP is 48, FP is 6, FN is 9, and TN is 87.

The CM of LR is shown in Table 5.

Table 5 LR's CM

		Real	
Predicted		Label 0	Label 1
	Label 0	55	2
	Label 1	2	91

As depicted in Table 5, LR correctly classified 134 tweets and incorrectly classified 16 tweets. For LR, TP is 55, FP is 2, FN is 2, and TN is 91.

The CM of NB is shown in Table 6.

Table 6 NB's CM

		Real	
Predicted		Label 0	Label 1
	Label 0	54	1
	Label 1	3	92

As shown in Table 6, NB correctly classified 134 tweets and incorrectly classified 16 tweets. For NB, TP is 54, FP is 1, FN is 3, and TN is 92.

The CM of RF is shown in Table 7.

Table 7 RF's CM

		Real	
Predicted		Label 0	Label 1
	Label 0	57	1
	Label 1	0	92

As shown in Table 7, RF correctly classified 149 tweets and incorrectly classified 1 tweets. For RF, TP is 57, FP is 1, FN is 0 and TN is 92.

The CM of SVM is shown in Table 8.

Table 8 SVM's CM

		Real	
		Label 0	Label 1
Predicted	Label 0	56	2
	Label 1	1	91

As seen in Table 8, SVM correctly classified 147 tweets and incorrectly classified 3 tweets. For SVM, TP is 56, FP is 2, FN is, 1 and TN is 91. The CM of XGBoost is shown in Table 9. As seen in Table 9, XGBoost correctly classified 148 tweets and incorrectly classified 2 tweets. For XGBoost, TP is 57, FP is 2, FN is 0 and TN is 91. Comparative experimental results for all algorithms are shown in Table 10 and Fig.3.

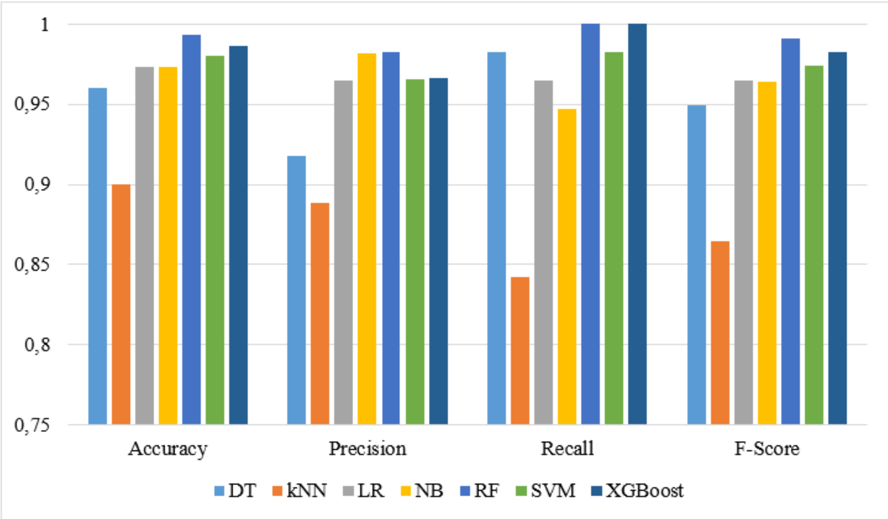

Figure 3 Comparative experimental results

Table 10 Comparative experimental results

Algorithm	Accuracy	Precision	Recall	F-Score
DT	0.9600	0.9180	0.9824	0.9491
kNN	0.9000	0.8888	0.8421	0.8648
LR	0.9733	0.9649	0.9649	0.9649
NB	0.9733	0.9818	0.9473	0.9642
RF	**0.9933**	**0.9827**	**1.0000**	**0.9912**
SVM	0.9800	0.9655	0.9824	0.9738
XGBoost	0.9866	0.9661	1.0000	0.9827

As seen in Table 10 and Figure 3, RF was more successful than all other compared algorithms. After RF, XGBoost, SVM, LR, NB, DT, and kNN were successful, respectively.

In the conducted experiments, RF proved to be more effective than DT as it considers the results of multiple decision trees and selects the outcome with the highest number of votes. The superior performance of RF in comparison to XGBoost can be attributed to the dataset's noisy nature. XGBoost builds individual decision trees sequentially, with each subsequent tree aiming to rectify the mistakes of the previously trained tree. RF trains each tree independently using random data samples. For this reason, RF has been more successful than linear classifiers such as LR and NB. The dataset's low noise level may provide an explanation for LR's superior performance in comparison to kNN. kNN is robust to noisy training data and is effective when the number of training samples is large.

SVM outperforms LR, NB, DT, and kNN, but SVM has a worse classification performance than RF. RF works with a combination of numeric and categorical features. When the features are at different scales, RF has the advantage that it can process the data as they are. SVM is based on maximizing the margin between different data points. Due to the structure of the data set, RF was more successful than SVM.

4. Conclusion

Natural disasters such as hurricanes, floods, and earthquakes occur in various parts of the world. It is challenging for people in the affected areas to cope with these disasters by their means. These disasters cause widespread loss of life, property, economic and environmental losses. One of the prominent features of the crisis and chaotic environment after disasters is communication problems. Social media is the most accessible communication tool that disaster victims can use in disasters. Primarily through Twitter, many aid messages are shared quickly. Social media was widely used in the severe earthquakes in Kahramanmaraş in Turkey. Unlike traditional media, social media plays a different role in disaster management. From this point of view, analyzing the posts on social media platforms during an earthquake and identifying the posts containing aid can provide rapid intervention to the places in need after the disaster.

This study analyzed the tweets sent after the Karamanmaraş earthquake to determine whether these tweets asked for aid or relief supplies. For this purpose, popular DT, kNN, LR, NB, RF, SVM, and XGBoost machine learning methods were used. These models were compared using success metrics, and the RF method had the highest success. Thus, a model was developed to classify the tweets posted during a disaster with high success. This model can make significant contributions to adequate and accurate disaster management. The developed model can be improved to make crisis management more effective after earthquakes and other disasters. For example, hybrid methods can be developed with deep learning models, and more significant results can be produced with larger datasets.

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Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Research Article

Slime mould algorithm based approaches to solve traffic insurance gross premiums of Türkiye

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ARTICLE INFO

Article history:
Received **December 6, 2023**
Revised **December 15, 2023**
Accepted **December 18, 2023**

Keywords:
Exponential model
Linear model
Quadratic model
Slime mould algorithm
Traffic insurance gross premiums problem

ABSTRACT

Highway traffic injuries are a major public health problem for all nations. As it is seen in the whole world, also in Türkiye, road traffic crashes are among the ones that cause death. As a result, road traffic congestion and fatalities represent a significant cost to national economies. The compulsory motor vehicle liability insurance is one of the most common types of insurance, both because it is compulsory and because the number of motor vehicles in Türkiye is very high. Therefore, estimation of the traffic insurance gross premiums (TIGP) problem is being an important problem for Türkiye as well as the other countries. In this study, in order to make some proper TIGP estimations for Türkiye, three different slime mould algorithm (SMA) methods such as SMA-Linear, SMA-Quadratic and SMA-Exponential are proposed. In the experiments, the population, number of vehicles and number of accidents and the observed TIGP historical data records of Türkiye taken from Turkish statistical institute (TUIK) and Turkish insurance association (TSB) for the years (2009-2020) have been used. First, the models are constructed using the SMA-Linear, SMA-Quadratic and SMA-Exponential methods, and then the methods based on the SMA-Linear, SMA-Quadratic and SMA-Exponential models are used to estimate the TIGP values for the years (2009-2020). According to the experiments, the best fitness values of 20 runs for SMA-Linear, SMA-Quadratic and SMA-Exponential are obtained 13.42221, 7.961962 and 294.3409, respectively. As a result, it is seen that SMA-Quadratic methods produces better or comparable performance on the problem dealt with this study in terms of solution quality and robustness.

1. Introduction

Transportation is one of the most important issues of our life and age. The highway, seaway, railway and airway are used for transportation [1]. The highway is the oldest form of transportation in history. And it is also the foundation of our transportation infrastructure [2]. Therefore, the external costs of road transport have been an important issue for political agenda over the last couple of decades [3]. The demand for and intensity of highway use has been on the rise, particularly as a result of population growth and the expansion of welfare status [4]. Due to the growing need for road transport, investments in road transport as well as appropriations and expenditures are increasing [2]. In general, the quality of inspection systems does not grow at the same rate as the number of vehicles in a country. As a result, enforcement is not at the desired level and traffic accidents occur due to inadequate enforcement [4, 5]. Traffic accidents are an unavoidable, albeit undesirable, consequence of road travel. They create a serious financial situation for individuals and society. Personal injury, property damage and lost time are the most noticeable

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DOI: 10.55195/jscai.1401378

personal costs [6].

Road traffic injuries are a major public health problem. Therefore, it is need of concerted efforts for effective and sustainable prevention [7]. According to the World Health Organization's (WHO), approximately 1.3 million lives are lost each year as a result of road traffic crashes. Between 20 and 50 million more suffer non-fatal injuries, and many are disabled as a result of their injuries [8]. In order to protect the safety of life and property of people and communities on the highways, each country has developed legal regulations according to its own laws. Thus, traffic insurance premiums are legally mandatory for vehicle owners [9].

Automobile liability insurance, which was first introduced in Denmark on March 20, 1918, began to spread to other countries after World War I. In the 1920s, the practice in Denmark was followed by other Scandinavian countries. In the same years, similar practices began to be seen in countries far from Europe. In fact, liability insurance for motor vehicles became mandatory in New Zealand and the US state of Massachusetts in 1927 [9, 10]. Road is the most used mode of transportation in Türkiye. It is used for both passenger and freight transportation. More than 90 % of all the transportation operations have been carried out through the road. As it is seen in the whole world, also in Türkiye, road traffic crashes are among the ones that cause death. As a result, road traffic congestion and fatalities represent a significant cost to national economies [1, 11]. Insurance activities started in Türkiye in 1870 after the Pera fire in Istanbul. Subsequently, traffic insurance became compulsory in Türkiye in 1983 [9, 12].

The compulsory motor vehicle liability insurance is one of the most common types of insurance, both because it is compulsory and because the number of motor vehicles in Türkiye is very high [13]. The insurance sector is developing under the influence of the rapid development of information technologies and product diversity. Forecast studies have also been carried out on the premium production of the sector and the premium production of the following year [4, 14].

Metaheuristic methods have been extensively studied by researchers in recent years for dealing with forecasting problems [4, 5, 15-22]. Main reasons of choosing meta-heuristic methods to solve optimization problems are that though meta-heuristic algorithms do not ensure to find the optimal solution, they provide the optimal or near optimal result, they are problem independent and easily adaptable to any optimization problem [23]. Therefore, in this work, linear, quadratic and exponential statistical regression forms are integrated with slime mold algorithm (SMA) for solving the traffic insurance gross premiums (TIGP) problem of Türkiye. In the experiments, observed traffic insurance gross premiums (OTIGP), population, number of vehicles and number of accidents historical records of Türkiye for the years (2009-2020) have been used. The OTIGP historical data records of Türkiye are taken from the Turkish insurance association (TSB) [4, 24], and the other data samples such as population, number of vehicles and number of accidents are taken from Turkish statistical institute (TUIK) [4, 25].

The rest of the paper is organized as follows: The basic SMA algorithm is explained in Section 2. The problem of the traffic insurance gross premiums is described in detail in Section 3. The experimental results of the proposed algorithms are presented in Section 4. Finally, the conclusions are presented in Section 5.

2. Slime Mould Algorithm (SMA)

Slime mould algorithm (SMA) is one of the stochastic optimization algorithm inspired from the concept of slime mould. In the absence of complete information, slime mould decide to the change its location with adopt heuristic or empirical rules based on the insufficient information currently available. A slime mould needs to move from its current location to a new location when the quality of the food source is being insufficient. According to the past experience when a slime mould encounter high-quality food, the probability of moving the current location decreases [26]. In addition, because of slime mould have some unique biological characteristics that allow them to consume different food sources simultaneously. Therefore, even if the slime mould has found a better food source, it can still split a component of the biomass to utilize both resources simultaneously if higher quality food is found [18, 27]. The mathematical scheme of the SMA is described in detail as follows:

2.1. Approach food

The slime mould can close the food source with the odour in the air. The mathematical expression of approaching behavior is provided in Eq. (1) and Eq. (2). The position of the current slime mould will be changed depending on the value of p. r is a random value in range of [0,1]. If the value of p is greater than the value of r, the current position of slime mould is updated according to Eq. (1), otherwise the current position of slime mould is updated according to Eq. (2).

$$\overrightarrow{X(t+1)} = \left\{ \overrightarrow{X_b(t)} + \overrightarrow{v_b} \cdot \left(\overrightarrow{W} \cdot \overrightarrow{X_A(t)} - \overrightarrow{X_B(t)} \right), \ r < p \right. \quad (1)$$

$$\overrightarrow{X(t+1)} = \overrightarrow{v_c} \cdot \overrightarrow{X(t)}, \ r >= p \quad (2)$$

Where, $\overrightarrow{v_b}$ refers to a parameter in range of $[-a, a]$, $\overrightarrow{v_c}$ value decreases linearly from one to zero. t refers to current iteration, $\vec{X}$ represents the slime mould population, $\overrightarrow{X_b}$ refers to position of slime mould with best fitness value, $\overrightarrow{X_A}$ and $\overrightarrow{X_B}$ positions represents the two different positions randomly selected from slime mould population. $\overrightarrow{W}$ shows the weight of slime mould population. p value is calculated with the fitness values of slime mould population and the fitness of $\overrightarrow{X_b}$ position.

$$p = \tanh \left| S(i) - DF \right| \quad (3)$$

Here, $i \in 1,2,\ldots,n$ and S(i) refers to the fitness values of $\vec{X}$ population, DF refers to the fitness value of the best position. The value of a is calculated as follows:

$$a = \operatorname{arctanh}\left(-\left(\frac{t}{\max_t} \right) + 1 \right) \quad (4)$$

The formulation of $\overrightarrow{W}$ is given as follows:

$$\overrightarrow{W(\mathrm{SmellIndex(i)})} = \begin{cases} 1 + r.\log\left(\frac{bF - S(i)}{bF - wF}\right) + 1, \text{condition} \\ 1 - r.\log\left(\frac{bF - S(i)}{bF - wF}\right) + 1, \ \text{others} \end{cases} \quad (5)$$

$$\mathrm{SmellIndex} = \mathrm{sort}(s) \quad (6)$$

Where condition shows that S(i) ranks first half of the population, r is a random value in range of [0,1], $\max_t$ indicates the total number of iteration, bF shows the best fitness value obtained in the current iteration, bF shows the worst fitness value obtained in the current iteration, SmellIndex holds the sequence of the fitness values from the best to worst.

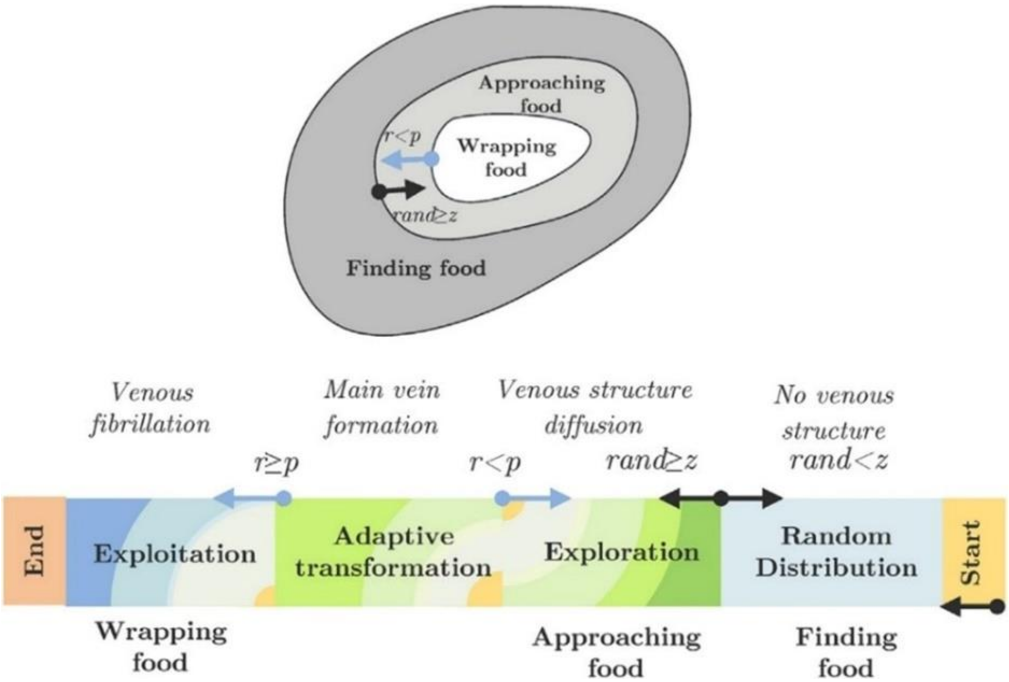

Figure 1 The algorithmic steps of SMA method [27]

2.2. Wrap food

This section presents the mathematical model of the contraction mode of venous tissue structure for slime mould in the search area. The higher the concentration of food contacted by the vein, the stronger the wave generated by the bio-oscillator, the faster the cytoplasm flows, and the thicker the vein. In the searching process of finds quality food sources, sometimes after a while the positions of the slime mould get stuck in the local optimum. In this case, a new position is generated for current position of slime mould individual. New position of current individual is generated with Eq. (7)

$$\overrightarrow{X^*} = rand().(UB - LB) + LB, \ \ rand < z \tag{7}$$

Where UB and LB show the upper limit and lower limit of a problem in search space, respectively, $rand()$ represents a random value in range of [0,1] and if $rand()$ value is smaller than the value of z, a new position is generated for current position of slime mould individual. After these explanations, the steps of the SMA and the framework of the SMA are presented in Figure (1) and Figure (2), respectively.

```
The initialization of algorithm
   Set the dimension of the problem (D)
   Set the number of individuals (N)
   Set the termination condition (max_t)
   Set the parameter z
   Generate N random position on the D-dimensional search space
   Calculate fitness value for slime mould population
   Sort slime mould population and find SmellIndex
   Find the best solution X_b, best fitness and worst fitness
   Set iteration counter t = 1
Searching process in solution space
  WHILE t <= max_t
  Calculate S value
  Calculate the fitness weight of each slime mould individual with Eq. (5)
  Calculate the value of a with Eq. (4)
  Calculate the value of b  (b = 1 − t/max_t)
   FOR Each individual of slime mould (X_t)
        IF rand < z
           Generate a new position for current individual with Eq. (7)
        ELSE
            Calculate p value with Eq. (3)
            Determine v_b and v_c
            Select randomly two different position ( X_A and X_B)
          FOR Each dimension of candidate solution
              IF rand < p
                Apply the Eq. (1) for creating a new position for current position
              ELSE
                Apply the Eq. (2) for creating a new position for current position
              END IF
         END FOR
        END IF
        Calculate fitness value for each individual of slime mould population
        Update the current position of the candidate solution
   END FOR
       Sort slime mould population and find SmellIndex
       Find the best solution X_b, best fitness and worst fitness
       t =t +1
Testing the termination condition
     IF Termination condition is not satisfied
        Go to Step searching process in solution space
     ELSE
        Report the best solution
     END WHILE
```

Figure 2 The framework of the basic SMA method [27]

3. Traffic Insurance Gross Premiums (TIGP) Problem

In this study, to create the estimation models of TIGP problem, three types of mathematical forms such as linear, quadratic and exponential forms are utilized with SMA technique. The population, number of vehicles and number of accidents indicators are used as input parameters, and the OTIGP indicator is used as an output parameter of linear, quadratic and exponential models. The linear, quadratic and exponential models used in this study are presented in Eq. (8), Eq. (9) and Eq. (10) respectively [17, 19, 28].

$$T_{\text{linear}} = W_1 + W_2.X_1 + W_3.X_2 + W_4.X_3 \tag{8}$$

Where, T_{linear} denotes to obtained TIGP value, W_1 denotes to independent coefficient, W_2, W_3 and W_4 denote to population, number of vehicles and number of accidents, respectively. X_1, X_2 and X_3 indicate to data samples for per a year. The calculation of quadratic model is presented in Eq. (11).

$$T_{\text{quadratic}} = W_1 + W_2.X_1 + W_3.X_2 + W_4.X_3 + ... \\ W_5.X_1.X_2 + W_6.X_1.X_3 + W_7.X_2.X_3 + ... \\ W_8.X_1^2 + W_9.X_2^2 + W_{10}.X_3^2 \quad (9)$$

Here, $T_{quadratic}$ denotes to obtained TIGP value, W_1 denotes to independent coefficient, $W_2 - W_{10}$ denote to population, number of vehicles and number of accidents indicators and their different combinations. X_1, X_2 and X_3 indicate to data samples for per a year. The calculation of exponential model is presented in Eq. (12).

$$T_{\text{exponential}} = W_1 + W_2.X_1{}^{W_3} + W_4.X_2{}^{W_5} + W_6.X_3{}^{W_7} \quad (10)$$

Where, $T_{exponential}$ refers to obtained TIGP value, W_1 denotes to independent coefficient, $W_2 - W_7$ represent denote to population, number of vehicles and number of accidents indicators and their different combinations. X_1, X_2 and X_3 indicate to data samples for per a year. The mathematical formulation of the fitness function between OTIGP and estimated traffic insurance gross premiums (ETIGP) is performed according to the Eq. (11) [16, 28].

$$\min \quad f(v) = \sum_{h=1}^{H} \left(T_h^{observed} - T_h^{estimated} \right) \quad (11)$$

Here, h denotes to a year of historical data samples and it is $h = 1, 2, ..., H$, H shows the total number of historical data samples. $T_h^{observed}$ and $T_h^{estimated}$ denote the OTIGP and ETIGP of hth data sample, respectively.

4. Experimental results

Linear, exponential and quadratic forms based three types of SMA techniques are implemented on the traffic insurance gross premiums problem: a case study of Türkiye. The historical data samples of Türkiye for the years (2009-2020) are directly taken from the study of Tefek and Arslan [4]. Population, number of vehicles and number of accidents indicators are used as input parameter of proposed models, and OTIGP indicator is used as output parameter of proposed models. Estimation models are created by using the historical data samples of Türkiye for the years (2009-2020) with proposed algorithms. All methods were coded in MATLAB and a laptop with WINDOWS 10 PRO OS, INTEL(R) CORE(TM) I7-6700HQ 2.60 GHZ CPU, 24 GB OF RAM was used in experiments. The SMA-Linear, SMA-Quadratic and SMA-Exponential algorithms are realized with 20 independent run. The number of slime mould population is chosen as 100 and the stopping criteria (max_t) is chosen as 5×10^3 for all methods. The search space for weight coefficients is assumed to be [-100, 100]. The experiments are reported as the Best, Worst, Mean, Median, Standard Division (Std.) of the fitness values for 20 runs and Amount of Errors (Error). Table 1 shows the historical data samples of Türkiye for the years (2009-2020).

Table 1 The OTIGP, population, number of vehicles and number of accidents dataset of Türkiye for the years (2009-2020) [4]

Year	OTIGP (10^9 TL)	Population (10^6)	Number of vehicles (10^6)	Number of accidents (10^5)
2009	1.971735	72.5	14.3167	10.53
2010	2.305579	73.7	15.0956	11.06
2011	2.700477	74.7	16.08953	12.29
2012	3.600106	75.6	17.03341	12.97
2013	4.965999	76.6	17.93945	12.07
2014	5.072925	77.7	18.82872	11.99
2015	6.810611	78.7	19.99447	13.13
2016	12.47027	79.8	21.09042	11.82
2017	12.49827	80.8	22.21895	12.03
2018	15.30191	82.03	22.86592	12.29
2019	18.0185	83.1	23.15698	11.67
2020	19.57144	83.6	24.14486	9.84

4.1. Compare the results of linear, quadratic, and exponential model based SMA methods

Table 2 shows the Best, Worst, Mean, Median and Std. of the fitness values of 20 independent runs for the compared algorithms. When Table 2 is examined, it is seen that the SMA-Quadratic has found the better results than compared algorithms in terms of the Best, Mean and Median fitness values. In addition, SMA-Linear method has found the better results for Worst and Std. criteria.

The convergence graph of the compared algorithms for mean fitness values is given Figure 3. As seen from Figure 3, the convergence of the SMA-Quadratic method is better than the other methods. The less convergence result is obtained from SMA-Exponential method. In addition, SMA-Exponential dropped to the local optimal solution in around of 500 iterations.

Table 2 The best, worst, mean, median fitness values and Std. of 20 runs for compared algorithms.

Algorithm	Criterion				
	Best	Worst	Mean	Median	Std.
SMA-Linear	13.42221	**15.08275**	13.91263	13.82632	**0.472677**
SMA-Quadratic	**7.961962**	21.76866	**13.56407**	**13.32446**	2.967005
SMA-Exponential	294.3409	458.0812	442.262	456.117	40.62914

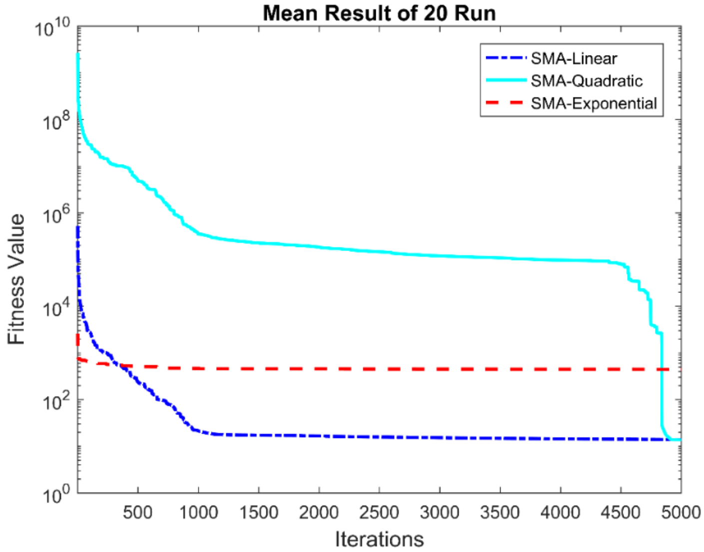

Figure 3 The convergence curves of mean results of fitness values of 20 runs for compared algorithms

Table 3 The OTIGP, ETIGP and Amount of Errors results for the years (2009-2020)

Year	OTIGP	SMA-Linear			SMA-Quadratic			SMA-Exponential		
		ETIGP	Error	Rank	ETIGP	Error	Rank	ETIGP	Error	Rank
2009	1.97173515	1.14774420	-0.82	2	**1.69065404**	**-0.28**	**1**	5.95538043	3.98	3
2010	2.30557857	**2.35800160**	**0.05**	**1**	2.36044617	0.05	2	6.39035949	4.08	3
2011	2.70047692	2.28505940	-0.42	2	**2.50952860**	**-0.19**	**1**	6.91009056	4.21	3
2012	3.60010599	2.81991490	-0.78	2	**3.06225810**	**-0.54**	**1**	7.37123366	3.77	3
2013	4.96599914	5.72164000	0.76	2	**5.01556966**	**0.05**	**1**	7.78759167	2.82	3
2014	5.07292488	7.63363950	2.56	2	**6.65267804**	**1.58**	**1**	8.17384190	3.10	3
2015	6.81061146	**7.69732680**	**0.89**	**1**	7.72610570	0.92	2	8.65016859	1.84	3
2016	12.47027356	**11.34313470**	**-1.13**	**1**	10.82468120	-1.65	2	9.07029012	-3.40	3
2017	12.49826970	**12.70569170**	**0.21**	**1**	13.06206187	0.56	2	9.47795992	-3.02	3
2018	15.30191038	14.33307380	-0.97	2	**15.11109297**	**-0.19**	**1**	9.70129776	-5.60	3
2019	18.01849968	16.91574150	-1.10	2	**17.13225249**	**-0.89**	**1**	9.79946157	-8.22	3
2020	19.57144198	20.33073370	0.76	2	**20.17997758**	**0.61**	**1**	10.12257187	-9.45	3

The OTIGP, ETIGP obtained by the proposed methods for the years (2009-2020) and the Amount of Errors are presented in Table 3. The difference between the OTIGP value and the ETIGP value indicates the Amount of Error. Table 3 shows that the ETIGP results of the SMA method based on the quadratic model are close to the OTIGP results when compared with the results of the other models. Besides, SMA-Quadratic provides the best results for 8 different years, and SMA-Linear provides the best results for 4 different years. Fewer results are obtained from SMA-Exponential method and there is no best result found for any year.

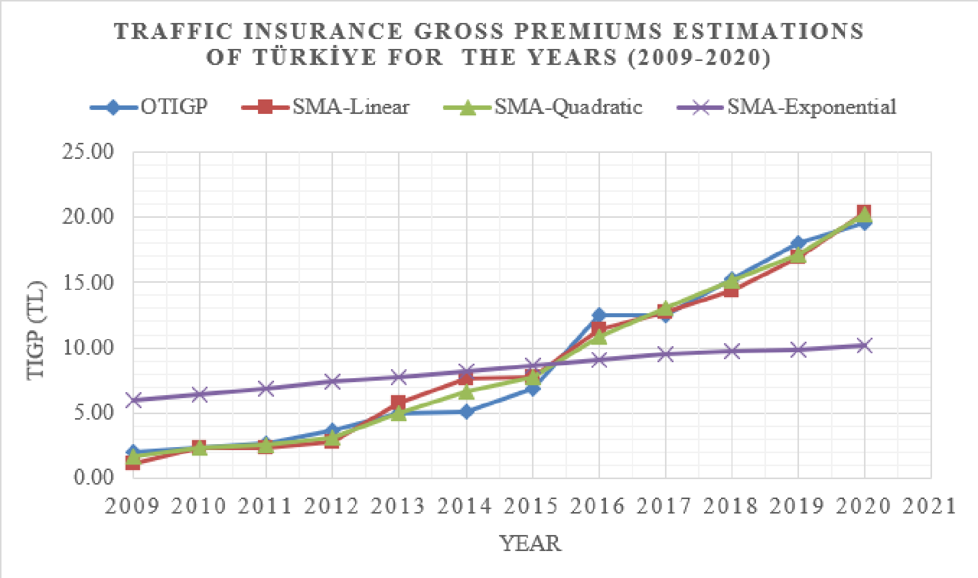

Figure 4 The OTIGP and the estimation values obtained by the proposed methods for the years (2009-2020)

The OTIGP of Türkiye for the years (2009-2020) and the estimation outcomes of linear, quadratic and exponential forms of SMA are illustrated in Figure 4. It can be seen that the TIGP of Türkiye is gradually increasing according to the OTIGP results of Türkiye for the years (2009-2020). Figure 4 shows that the ETIGP results of SMA-Quadratic are more similar to the OTIGP results when compared to the SMA-Linear and SMA-Exponential.

Table 4 The weight values, best fitness values and total error obtained by compared methods

Algorithm	Weight Coefficients	Best Fitness Value	Total Error	Total Rank
SMA-Linear	[-100.00 1.5860 0.0623 -1.3991]	13.42	10.44	20
SMA-Quadratic	[0.5374 -0.0509 -3.7062 0.1792 0.0124 0.0017 0.0025 0.0054 0.0880 -0.0423]	**7.96**	**7.50**	**16**
SMA-Exponential	[71.4774 67.6793 -75.7634 -91.5613 -0.1257 -32.2170 -43.3196]	294.34	53.50	36

The weight coefficients, best fitness values, total errors and total ranks found by the linear, quadratic, and exponential model-based SMA algorithms for the years (2009-2020) are shown in Table 4. The total error is calculated as the sum of the absolute difference between the OTIGP and ETIGP values for each year. According to the Table 6, the experimental results of SMA-Quadratic method is greater than the other compared methods in terms of the best fitness values and total error criteria. If we examine Table 4, we can see that the performance of the SMA-Exponential is lower than the results obtained by the other methods. The second-best results are obtained by SMA-Linear method. The best fitness value, total error and total rank obtained by the SMA-Quadratic method are 7.96, 7.50 and 16 respectively.

5. Conclusions

This study focuses on creating an appropriate estimation model for solving traffic insurance gross premiums problem of Türkiye. SMA is a population based stochastic optimization algorithm proposed by Li et al. (2020) [27] for solving continuous optimization problem. The slime mould expression is represented to Physarum polycephalum and the reason of called as slime mould is it was first classified as a fungus. Road traffic injuries are a major public health problem. As it is seen in the whole world, also in Türkiye, road traffic crashes are among the ones that cause death. As a result, road traffic congestion and fatalities represent a significant cost to national economies. Therefore, in this study, three different SMA methods such as SMA-Linear, SMA-Quadratic and SMA-Exponential are proposed and implemented on traffic insurance gross premiums problem of Türkiye. In the experiments, the population, number of vehicles and number of accidents and the observed TIGP historical data records of Türkiye taken from TUIK and TSB for the years (2009-2020) have been used [24, 25]. After creating the regression models with SMA-Linear, SMA-Quadratic and SMA-Exponential methods, the proposed methods are implemented on the dataset of Türkiye for the years (2009-2020) in order to estimate the TIGP values. When the experimental results and comparisons are examined, it can be seen that the SMA-Quadratic method is obtained competitive and effective results for estimating the traffic insurance gross premiums.

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Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Research Article

The Importance of Clean Energy and Technology in the Development of Smart Cities

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ARTICLE INFO

Article history:
Received **December 13, 2023**
Revised **December 27, 2023**
Accepted **December 30, 2023**

Keywords:
Smart Cities
Clean Energy
CO2 Emissions
Sustainability

ABSTRACT

In today's global context, reducing CO2 emissions and mitigating environmental impacts has become an important issue, leading to the inclusion of smart cities among the top priorities of every country. This article aims to provide solutions for creating appropriate policies and overcoming obstacles in this field, with a focus on the importance of clean energy in the development of smart cities. Specifically, by focusing on three important sectors, namely Energy, Transportation, and Buildings, the aim is to help create efficient roadmaps for developing smart cities. To achieve this goal, successful policies and strategies implemented in successful cities will be examined to overcome the barriers in these sectors and achieve smart city status. The article emphasizes the importance of local government and stakeholder collaboration. This collaboration plays a critical role in creating appropriate policies for increasing the use of clean energy in different sectors, as the ideas of politicians and energy experts cannot be implemented without the support and participation of local governments. Therefore, the cooperation and support of local governments and stakeholders are of great importance for the development of smart cities. In short, the article emphasizes the importance of clean energy in the development of smart cities, provides recommendations for identifying appropriate policies and overcoming barriers, and highlights the critical role of local government and stakeholder collaboration. Therefore, this collaboration can be considered as a successful step towards the development of smart cities.

1. Introduction

Humanity, facing critical challenges such as global warming and population growth, considers the transition to smart cities as a necessity [1], [2]. Despite the numerous benefits of smart cities, there are many factors hindering their development and, therefore, appropriate policies and planning must be implemented to successfully apply them [3], [4]. Additionally, appropriate management of infrastructure in the energy, transportation, and building sectors is a fundamental aspect of smart cities [5], [6]. The use of clean energy plays an important role in reducing CO2 emissions and is necessary for the comfort and welfare of citizens [7]. The provision of high-quality and safe city services is also an important factor [8].

This study aims to examine the development of smart cities [8], [9] and appropriate policies in the energy, transportation [10], [11], and building sectors [12]. Previous studies [6], [8], [9], [13], [14] have attempted to provide suitable policies for the development of smart cities in successful projects. In these studies, four important topics were examined: provider, consumer, regulator, and enabler, the importance of technologies for smart cities was investigated, a study was conducted that emphasized the relationship between city-energy-sustainability

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DOI: 10.55195/jscai.1404604

based on smart energy cities, and the main components, design tools, efficiency, and integration possibilities of renewable energy sources in smart cities were analyzed. In addition, the performance of a smart approach based on the integration of various technologies was also examined.

This study focuses on the development of smart cities and draws attention to the importance of appropriate policies in the energy, transportation, and building sectors. Appropriate policies must be implemented for the successful application of smart cities. These policies can promote the development of smart cities, reduce environmental impacts, and increase the comfort and welfare of citizens.

This article highlights several important aspects of the development of smart cities. It focuses on the role of suppliers, consumers, regulators and project promoters, as well as the importance of technology in smart cities. It examines the relationship between cities, energy and sustainability, particularly in the context of smart energy cities. The article also looks at the integration of renewable energy sources in smart cities, addressing components, design tools, efficiency and integration opportunities. It also evaluates the performance of smart approaches that integrate different technologies.

The study emphasizes the importance of appropriate policy measures in the areas of energy, transport and buildings for the successful development of smart cities. These measures are crucial for promoting the development of smart cities, reducing environmental impacts and improving the comfort and well-being of citizens.

Key points of the article include:

- The importance of reducing CO_2 emissions and mitigating environmental impacts in a global context, with smart cities being a top priority.
- A focus on the energy, transport and building sectors to find solutions for creating efficient roadmaps for smart city development.
- An examination of successful policies and strategies in different cities to address the challenges in these sectors and achieve smart city status.
- The crucial role of local authorities and co-operation with stakeholders in developing strategies to increase the use of clean energy.
- Emphasizing clean energy as an important component in the development of smart cities, including recommendations for formulating strategies and removing barriers.

2. Motivation

Smart cities offer a significant opportunity to improve citizens' quality of life. Therefore, cities need to assess the benefits of smart cities in order to improve service quality. The progress of efforts to effectively deploy smart cities is observed to be positive, particularly in areas such as energy management, municipal services, public safety, traffic management, and building resilience, which include the use of Internet of Things (IoT) technologies [15]–[18]. The definition of smart cities is based on three fundamental elements: IoT, big data analytics, and cloud computing. The use of these elements helps cities optimize their services and improve citizens' quality of life. For example, in the field of energy management [19], smart grids can be used to manage energy consumption and production, reducing energy consumption in cities and enabling a transition to sustainable energy sources. Smart transportation systems can be used to optimize traffic flow and reduce traffic problems in cities [7], [12]. Additionally, citizens can access public transportation services more easily and effectively. In the building sector, smart buildings can be used to control energy consumption and improve building resilience. Smart buildings can also be effectively utilized in areas such as building security, fire prevention, and firefighting. In addition to the benefits provided by smart cities, the challenges encountered in implementing smart cities should also be addressed. These challenges include inadequate technological infrastructure, investment costs, and low technological infrastructure and insufficient funding in developing countries.

3. Methodology

The main purpose of this article is to emphasize the importance of clean energy and present a more accurate perspective on smart city development. This goal can be achieved by overcoming obstacles in various sectors and providing appropriate solutions, focusing on the successes of applied policies. Energy, transportation, and buildings have a decisive role in the successful implementation of smart cities. In this context, the development of smart cities is discussed in relation to clean energy sources, technologies used in smart cities, and the impact of clean energy and technology in smart cities.

The conclusion and discussion sections increase our knowledge and understanding of appropriate policies and necessary actions for a city's transformation into a smart city. In this context, the use of clean energy sources and adoption of smart technologies are important factors for the successful development of smart cities.

Overall, this article emphasizes the importance of clean energy in smart city development. To this end, it aims to increase our knowledge and understanding of appropriate policies and actions for transforming a city into a smart city by reviewing research on the development of smart cities, clean energy sources, technologies used in smart cities, and the impact of clean energy and technology in smart cities.

3.1. Development of Smart Cities

Smart cities are a rapidly developing concept in urban planning, aiming to use information and communication technologies (ICT) to enhance the quality of life and sustainability of cities. Developing smart cities requires the integration of various technological components such as sensors, networks, and data analytics with urban systems such as transportation, energy, and public services. The goal is to create an efficient and livable urban environment that responds to the needs of citizens and supports economic growth [20], [21]. An example project image in this regard is given in Figure 1.

Figure 1 Relevant components of smart city areas [22]

The concept of smart cities has emerged globally in response to increasing urbanization and environmental problems faced by cities. The United Nations estimates that by 2050, 68% of the world's population will live in urban areas, up from 55% in 2018 [23]–[25] .This rapid growth puts pressure on urban infrastructure and services, leading to density, pollution, and resource depletion. Smart cities offer a solution to these problems by optimizing urban systems using technology and increasing resource efficiency.

The development of smart cities requires collaboration among various stakeholders, such as governments, the private sector, and citizens. Governments play an important role in facilitating the adoption of smart technologies by developing policies and regulations and encouraging investment in urban infrastructure. The private sector is responsible for developing and implementing smart technologies such as energy-efficient buildings and smart transportation systems. Citizens play an important role in providing feedback and participation in the development of smart city initiatives [20], [26]. Overall, the development of smart cities is a complex and dynamic process that requires the integration of various technological, social, and economic factors.

3.2. Clean Energy Sources

Clean energy sources are renewable sources that have little or no negative impact on the environment and can be sustained in a renewable manner [27], [28]. These energy sources are commonly referred to as renewable energy sources because they do not deplete with use and can be replenished. In contrast, fossil fuels such as coal and oil are limited resources that are rapidly depleting and have significant detrimental effects on the environment. There are several types of clean energy sources [29]–[35], including those shown in Figure 2.

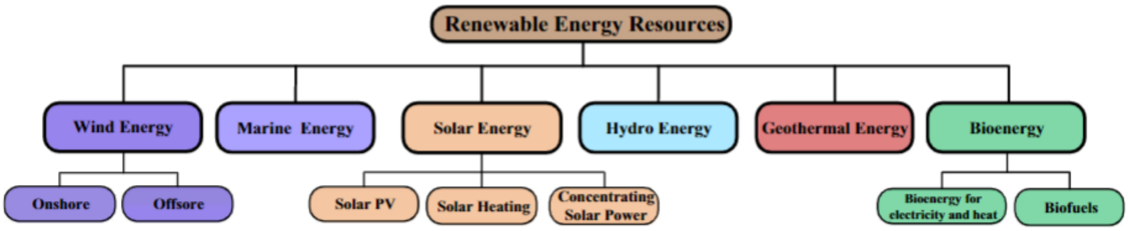

Figure 1 Renewable Energy Sources [36]

• ***Solar energy:*** Energy obtained from sunlight. Solar panels are used to capture this energy and convert it into usable electricity. Solar energy is abundantly available and can be used to power homes, businesses, and even entire cities.

• ***Wind energy:*** Energy produced by the wind. Wind turbines are used to capture this energy and convert it into usable electricity. Wind energy is also abundantly available and can be used to power homes, businesses, and even entire cities.

• ***Hydroelectric energy:*** Energy obtained from the flow of water. Hydroelectric power plants are used to capture this energy and convert it into usable electricity. Hydroelectric energy is also abundantly available and can be used to power homes, businesses, and even entire cities.

• ***Geothermal energy:*** Energy obtained from the heat of the Earth. Geothermal power plants are used to capture this energy and convert it into usable electricity. Geothermal energy is also abundantly available and can be used to power homes, businesses, and even entire cities.

• ***Biomass energy:*** Energy obtained from organic materials such as wood and crops. Biomass power plants are used to capture this energy and convert it into usable electricity. Biomass energy is also abundantly available and can be used to power homes, businesses, and even entire cities.

All of these clean energy sources have various advantages over fossil fuels. Firstly, they do not produce greenhouse gases that contribute to global warming and climate change. Secondly, they are renewable and replenishable unlike fossil fuels. Thirdly, they do not produce harmful pollutants that can be detrimental to human health and the environment. Finally, as technology advances and demand increases, they are becoming increasingly cost-effective.

3.3. Technologies Used in Smart Cities

Smart cities are an emerging concept that aims to optimize urban infrastructure and services using technology [37], [38]. Various technologies used in smart cities enable efficient resource management, reduction in energy consumption, and an overall improvement in quality of life.

One of the fundamental technologies used in smart cities is the Internet of Things (IoT), which connects devices and sensors embedded in urban infrastructure, such as traffic lights, waste management systems, and public transportation, to a central network [39], [40]. IoT sensors collect and transmit data that can be analyzed for optimizing resource utilization, reducing energy consumption, and increasing service efficiency. Figure 3 illustrates the application areas of Cloud-IoT.

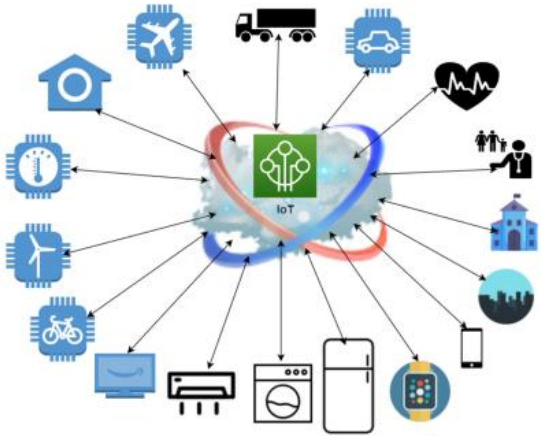

Figure 3 Cloud-IoT application areas [41]

Artificial Intelligence (AI) is used to analyze the large amounts of data generated by IoT sensors in smart cities to predict future events, optimize resource usage, and improve service efficiency. AI-supported systems can detect patterns in data and make real-time decisions, enabling proactive problem-solving and improving citizens' quality of life. For example, AI-supported traffic management systems can optimize traffic flow, reduce congestion, and enhance transportation services.

Smart cities also reduce their dependence on fossil fuels and mitigate the effects of climate change by using renewable energy sources such as solar, wind, and geothermal energy [42]. These technologies enable cities to generate their own electricity, reduce carbon emissions, and improve air quality.

Furthermore, smart cities communicate with citizens, provide access to city services, and enable citizen participation through various digital platforms such as mobile applications, social media, and websites. These platforms can increase citizen participation, transparency, and accountability, thereby enhancing trust between citizens and government.

3.4. The Impact of Clean Energy and Technology on Smart Cities

Smart cities are urban areas that utilize data and technology to enhance the quality of life for citizens while reducing their environmental impact. The concept of smart cities has gained popularity in recent years due to the need for more sustainable and efficient urban development. One of the most important components of smart cities is the use of clean energy sources and technology.

Clean energy sources such as wind, solar, and geothermal energy are becoming increasingly popular in smart cities due to their environmental benefits and potential to lower energy costs [30], [34], [42]. These energy sources are also more reliable than traditional fossil fuels as they are not subject to price fluctuations caused by global political tensions or supply-demand imbalances.

In addition to reducing environmental impact, smart cities also utilize various technologies to increase energy efficiency and reduce emissions. For example, sensors and meters can be used to monitor and manage energy use in buildings, while electric vehicles and public transportation systems can help reduce the number of cars on the road and mitigate air pollution.

Clean energy and technology can also have a positive impact on the economy of smart cities. The adoption of clean energy sources can create new jobs in sectors such as renewable energy and energy efficiency, while the implementation of smart technologies can enhance the efficiency and productivity of businesses and government services [43].

In general, the use of clean energy and technology in smart cities has the potential to reduce environmental impact, create economic benefits, and enhance citizens' quality of life. As the need for sustainable urban development continues to grow, we can expect to see more cities adopting clean energy and technology as key components of smart city strategies.

Another important aspect of clean energy and technology in smart cities is their ability to increase resilience and prepare for potential disruptions. With the effects of climate change becoming more pronounced, cities need to be able to withstand extreme weather events and other crises. Clean energy sources such as solar panels and wind turbines can continue to generate electricity even during power outages, providing a reliable energy source for critical infrastructure such as hospitals and emergency services [44], [45].

Smart technologies can also help cities manage their resources more effectively in emergency situations. Real-time data from sensors can help identify areas that are in greatest need of resources, and autonomous systems can be used to quickly deliver essential supplies to these areas. Figure 4 presents a visualization of technology focused on smart cities.

Figure 4 Smart city-focused technologies [46]

However, there are also challenges related to the implementation of clean energy and technology in smart cities. One of the main challenges is the cost of implementing these technologies. While clean energy sources are becoming more affordable, the initial investment required for infrastructure and technology can be a barrier for some cities.

Another challenge is the need for skilled workers and expertise to maintain and operate these systems. As technology use becomes more widespread in cities, workers with specialized skills in areas such as data analytics, cybersecurity, and renewable energy will be needed.

In conclusion, the adoption of clean energy sources and technology is a key component of smart cities. These technologies can help reduce environmental impact, increase economic benefits, and improve resilience against potential disruptions. While there are challenges associated with their implementation, the benefits outweigh the costs and provide a path towards a more sustainable and efficient urban future [47], [48].

4. Result

Smart cities consist of six important components: smart people, smart governance, smart living, smart mobility, smart environment, and smart economy. All these components are equally important and their integration is crucial for creating a smart city. Therefore, it is important to structure the integration of each component properly.

This integration requires the use of technological advancements. The use of technology in smart cities can result in effective outcomes in many areas. However, a solely technology-based approach is not sufficient for smart cities. It is crucial for governments and policy makers to establish and implement appropriate policies for the energy, transportation, and building sectors. This way, smart cities can achieve goals such as sustainability, efficiency, safety, and livability.

Tools such as systems that monitor energy consumption in new buildings, new technologies that promote energy conservation, and building management systems can assist in the development of zero-energy buildings. Successful smart cities have adopted policies and strategies in the energy, transportation, and building sectors that largely focus on the expansion of new technologies, the use of renewable energy, and energy conservation.

Policies in smart cities can vary depending on the characteristics of each city. For the sustainability of cities, governments and stakeholders must collaborate. Local governments can achieve objectives such as clean air, low-consumption technologies, and new transportation systems. Stakeholders can also support the policies of local governments to achieve these objectives.

In conclusion, the development of smart cities can be achieved by the integration of various factors such as the use of technology, the establishment and implementation of appropriate policies, and the integration of components. Therefore, it is important for research on the development of smart cities to consider these factors.

5. Conclusion

The development of smart cities is facing significant challenges due to the necessity to reduce CO2 emissions and meet energy demand. This study aims to identify and present effective policies related to the energy, transportation, and building sectors. Previous studies have shown that technologies and smart vehicles play a significant role in increasing efficiency and effectiveness in every sector. Solutions such as the use of IoT, the development of lighting programs, and energy conservation have led to successful results in smart cities concerning energy loss prevention. In the transportation sector, the use of electric vehicles (EVs) and smart transportation systems with traffic management ensure higher safety and timely transportation. In the building sector, IoT use results in reduced energy consumption and enables real-time adjustment of electricity consumption, management of ventilation and lighting, and adjustment of energy loads for grids.

Past policies, strategies, and technologies' successes and failures should be reviewed. However, it should be noted that each country and city has different needs, and what works in one region or country may not work elsewhere. Additionally, local governments' attention to stakeholder needs and cooperation among them, especially the use of stakeholder knowledge by local governments, positively impacts smart city development.

As a result, focusing on efficient policies in the development of green energy and solutions for attracting investment in clean energy development is crucial, based on the results of this study.

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Journal of Soft Computing and Artificial Intelligence

Journal homepage: https://dergipark.org.tr/en/pub/jscai

International Open Access

Volume 04
Issue 02

December, 2023

Research Article

Embodiment in Virtual Reality and Augmented Reality Games: An Investigation on User Interface Haptic Controllers

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ARTICLE INFO

Article history:
Received December 24, 2023
Revised December 28, 2023
Accepted December 30, 2023

Keywords:
Embodiment
Virtual Reality
Augmented Reality
Gaming
User Interface
Haptic Controllers

ABSTRACT

Undoubtedly, virtual reality technologies stand out as one of the most rapidly expanding domains in the present era. Apart from features like clarity of vision, viewing angle and time distortion that are improving daily, user interfaces are another crucial part of this technology that is not talked about much but must be. This study investigates and summarizes the literature on wearable technology and haptic controllers, which serve as the player's interface between virtual and augmented reality. The controllers and devices we investigate, try to achieve a holistic approach in the experience thus it appears to be a rich soil for future studies. Although many technological advancements and entirely new ones are anticipated, a thorough analysis of the phenomena of interaction, participation, and integration, as well as embodiment and presence, should shed light on the question of its scope, depth, assessment, and limitations.

1. Introduction

The notion that digital environments could deliver a fully immersive experience has often been regarded as a "techno-fantasy" within the realm of science fiction [1]. Since game engines and 3D game universes are becoming more plausible and realistic than ever before, with the greater complexity of haptic technologies and interfaces based on natural bodily action patterns, creating an ideal standard for game design. It is apparent that games appeal to larger audiences as more people play them.

Juul claims that the rise in prevalence can be mainly attributed to the widespread acceptance of mimetic interfaces, where the player's physical actions closely mirror the in-game activities displayed on the screen [2]. Similarly, as Skalski et al. posit; controllers incorporating more intuitive mappings empower players to effortlessly connect with mental representations of real-world actions, thereby facilitating their immersion in the game [3].

De Castell with Jenson in The Entrepreneurial Gamer: Re-gendering the Order of Play, argue that game controllers designed in specific shapes and forms (e.g., a musical instrument) such as units with motion-sensitive sensors, provide different gaming styles and experiences [4]. Additionally, these formats appear to be used for educational purposes. In other words, digital interaction forms not only use a large part and/or the entire body as a control unit, but also begin to transform human-computer interaction into a different point, with increasingly natural and mimetic movement forms. In addition, tactile feedback such as -frequently used- vibration can be considered to support the sense of digital embodiment.

According to Dourish, the evolution of human computer interaction has progressed through different phases, culminating in a transition from statical graphical user interfaces towards more concrete, communal, and incarnate methods.

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DOI: 10.55195/jscai.1409156

In particular, the concluding phase is advantageous in enhancing “the mechanics of daily living” and “the manner in which we encounter everyday life” [5]. The literary works articulates many opinions on the contributions and effects of technological equipment to the gaming experience. However, these views seem to be not sufficient to lead us to a conclusion. Similarly, Hufnal et al. affirm; “whether the gaming devices are the easiest to study and research, or the most realistic ones are ‘more successful’ is challenging to articulate and characterize to intricate interplay between human physcology, perception, and their interaction with engineering systems” [6].

2. Embodiment in Virtual Reality and Augmented Reality Games

Embodiment in games can also be thought of as “a concept in which players identify and experience themselves with the bodies of these characters while interacting with virtual characters”. Players use body movements to perform actions in the game and transfer them to the character’s body. In this process, players’ perceptions, movements, and emotional experiences are reflected in the body of the virtual character, and players feel merged with the body of this character [2]. Embodiment allows players to fully immerse themselves in the game world and makes the gaming experience more intense and impressive. Players experience the game world through the body of the character they control. explore, interact with the environment, and perform tasks. In addition, embodiment can also be considered to help players gain a perception of presence in the virtual world with a deeper connection the game realm they experience [5].

Embodiment in games can be achieved through various technologies and interfaces. As motion sensors and virtual reality headsets allow players to transfer real body movements to the virtual character. These technologies provide more realistic and impressive aspect to embodiment experience. This concept also plays a significant role in game design. Game developers use mechanics, controls, and visual elements that support embodiment to enable players to connect with their characters. In this way, players become more deeply involved in the game world and cope with the challenges of the game using the character’s bodily functions.

3. Aim and Contribution

There are currently a multitude of controllers for interacting with virtual environments and artificial reality, each with their advantages and limitations, as we stated earlier.

Although some controversial devices may not be successful in sales or are only at the prototype stage, it is possible to develop predictions about their potential and the contribution they will make to future academic studies. Additionally, in Lankoski’s discourse “feedback from players and users also helps shape these predictions” [7]. So as instance, how can we replicate actions such as keyboard typing or using a scalpel in a simulation? Which technology offers the most intuitive user experience? What methods can be employed to create a sense of user immersion in the virtual world while facilitating interaction with the real world?

This research aims to cover the most recent research specifically on game experience with devices, wearable tech, and controllers with more natural mappings.

4. Embodied Interaction and User Interface Haptics

Virtual reality technologies are indubitably one of the fastest growing areas today. In addition to elements that are getting better day by day, such as clarity of vision, viewing angle and time distortion, another important aspect of this technology that is overlooked very often but merits consideration is user interfaces. Because these interfaces are the first station where the subject and the virtual (digital) environment meet. For decades the controllers and controllers of personal computers were limited to devices such as mouse and keyboards. Finally, contemporary approaches encompass a range of more advanced methods for controlling the virtual environment. In addition to traditional input tools like hands, alternative body parts such as our feet for navigating the virtual world of eyes for eye tracking even are now viable options.

However, according to Bernatchez and Jean-Marc, after years of getting used to two-dimensional computer planes, it can be initiating the process of contemplating three-dimensional movement and visualization can pose a challenge and may seem intricate for us [8]. Yet, adhering to Steven LaValle’s Universal Simulation Principle, “any interaction mechanism occurring in the real world can be simulated in artificial reality” [9].

In the most recent literature review, Sudha et al. [10], Bachmann et al. [11], Perret and Poorten [12], Li et al. [13], Boletsis and Cedergren [14] and Tomáš Nováček and Marcel Jirina’s research published in 2022 stand out [15]. Especially the studies of

Nováček and Jirina allegedly are among the most comprehensive studies in the field. Almost all studies conducted until their research published in 2022 are of daily use and prime importance to users, as most controllers and devices are a compendium of practical devices used by designers in industry, work simulators, human-computer interface research, or by ordinary individuals such as amateur developers, gamers, or researchers. Nováček and Jirina say "When discussing the controllers of a user interface, the opinions and experiences of ordinary users are important," in this regard. Because evidently the "effectiveness of the user interface controller can be gauged solely by the level of satisfaction expressed by users [15]. Their efforts substantiating this perspective encompass not only research articles and official technical specifications but also user reviews and comments from sources beyond academic realms.

Game controllers are commonly categorized based on two primary criteria: (i) whether they are hand-based or foot-based, and (ii) the technologies employed for measurements, such as optical or acoustic tracking. Referred to as the 'digitalization of movement' in some sources, motion tracking technologies have gained popularity in contemporary literature. This popularity is attributed to their capability to capture natural movements, allowing users to walk, use their hands, and even fingers, with these actions seamlessly transferred to the virtual world. This technology plays a crucial role in creating virtual avatars in both virtual reality and augmented reality, contributing to a truly immersive experience an aspect our research also explores. Initially, our focus is on investigating the realm of hand-based or foot-based haptics. We initially, aim to investigate the hand-based or foot-based haptics.

In early 2000's Nintendo Wii had a surprisingly significant success compared to its era [16]. After this success, Kinect of Microsoft and PS Move of Sony also try using motion control (Figure 1).

Figure 1 Microsoft Wii Kinect and Sony PS Move

Despite this significant success, Leyvand et al. [17] claims that immersion without any intermediary controllers has long been considered "the holy grail of game designers and developers". However, assessments on platforms like Metacritic reveal that not all games effectively employ this type of interaction [18].

Optical tracking technologies, which provide gaming experiences without any intermediary controls, employ an imaging device, such as a camera, to monitor the user. The user's position is determined, and their movements are tracked by one or more sources typically mounted on the walls of the monitored room. These sources emit an optical signal, often in the form of infrared light, which is then captured by the imaging device.

Tjaden et al., divide gaming devices, which are widely used in the industry, into active and passive, depending on 'how the signal received from the user is sent to the device and processed'. And it suggests signals from active tracking as 'more precise' than passive optical tracking [19].

Especially, outside-in tracking technology, frequently encountered in recent years in in-game immersion studies, takes an approach to adopt whole-body engagement by eliminating the necessity of a gaming input device [15]. These devices have the capability to track player movements in real-time and react to particular gestures and spoken instructions through an infrared sensor bar [19] and microphone. In this context, at first glance, it seems appropriate to address the phenomenon of embodiment, which was offered in Merleau-Ponty's phenomenological perspective on perception [20].

However, when investigated in depth, its obvious shortcomings become evident even as a mere 'tool'.

The most prominent device with this mechanic is initial iteration of Microsoft's Xbox Kinect, released in 2010, incorporates a RGB color video camera, a depth sensor, and an array of microphones (Figure 2).

Figure 2 Microsoft Xbox Kinect

This first-generation device is based on the principle of patterned light in which an infrared pattern is projected onto the user where it calculates the user's distance and movements by detecting deformations in the camera's perception pattern and identifies and monitors forty-eight key points on the user's body [21]. With this structure, it can metaphorically be considered as a 'third eye' without interfering with the player's in-game behavior. However, according to Cong and Winters, "Unfortunately, Kinect did not achieve commercial success, and even the sales of its second-generation successor are underwhelming" [22]. As a matter of fact, Microsoft halts product support after the second-generation Kinect, which relies on the Time of Flight (TOF) principle, involving the measurement of the time it takes for the signal to reach a tracked object and return to the source [21]. And within 2020, it launched a new sensor device, Kinect Azure. On this instance, the application is not for gaming but rather for industry and business. Sarbolandi et al. interprets this situation as such technologies being far from promising for the gaming world [23]. It is discernible in the literature that among the most utilized types of motion tracking systems that relies on optical sensors is ART-Advanced Real-time Tracking [24]. ART, which uses both active and passive functions and provides outside-in monitoring, launched TRACKPACK products in 2015 for broader areas and SMARTTRACK 2019 for surface tracking.

The precision and precision of tracking depend on the number of tracking cameras [25]. This aspect holds considerable promise for potential gaming research. It was first launched in 2012 under the name OptiTrack Primex 41 and then relaunched in 2020 with advancements [25].

The OptiTrack Primex 41 (2020, 2023) is preferred by game manufacturers and researchers due to its high tracking range and the ability for pairing with any OptiTrack Prime camera to establish an optimal setup. However, it is observed that this approach has not yet been sufficiently included in academic research.

In 2016, software company WorldViz launched the Precise Positional Tracking (PPT), a warehouse-scale tracking system [26]. What is distinctive about this system for game studies and our research is that its capability extends beyond WorldViz Vizard and includes support for game development engines like Epic Games' [27] Unreal Engine and Unity Technologies' software Unity [28], enabling interface integration as seen on Figure 3 below. In this mechanism, optical tracking can be refined by incorporating an acceleration-based tracking system, either integrated into the controller and/or attached as a clip to a Head-Mounted Display (HMD) [26].

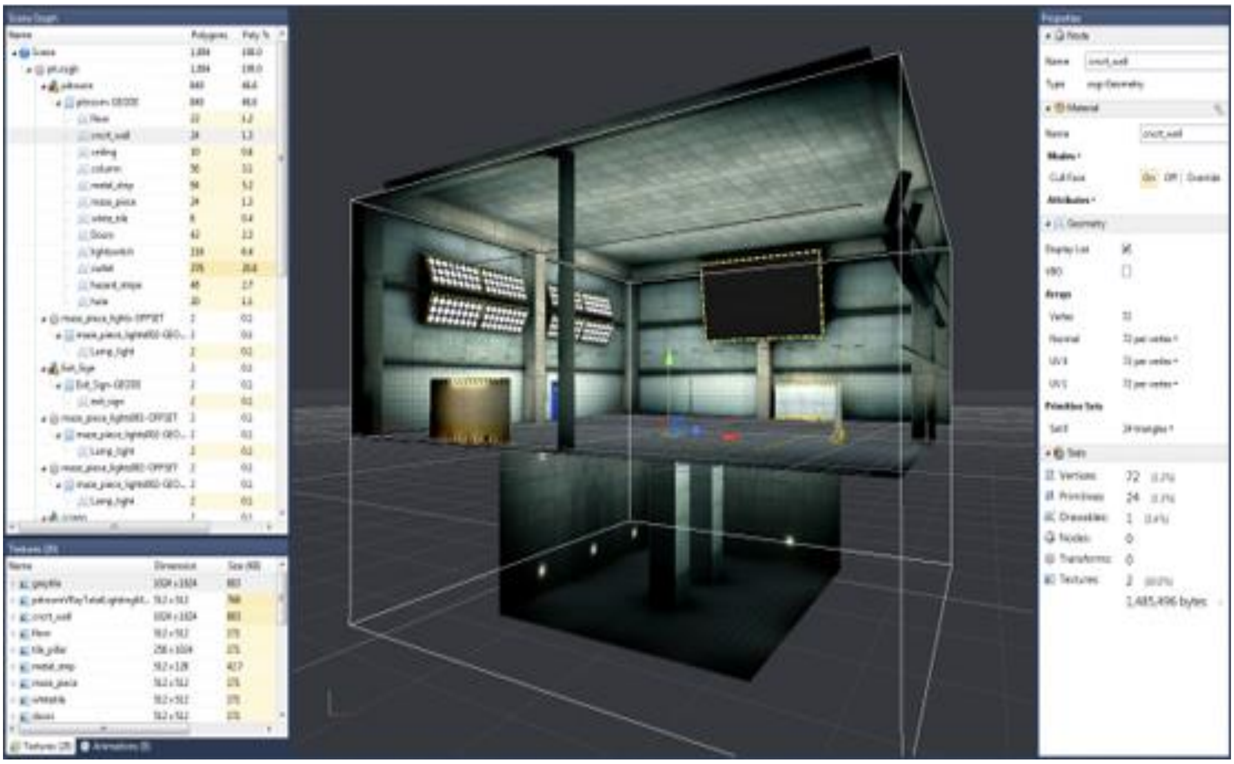

Figure 3 WorldViz Vizard Unity Interface Integration

Similarly, Vicon, one amongst the earliest systems according to scholarly works, provides a full-body marker, a kind of 'invisible suit of markers', to track users (Figure 4), [27], [28].

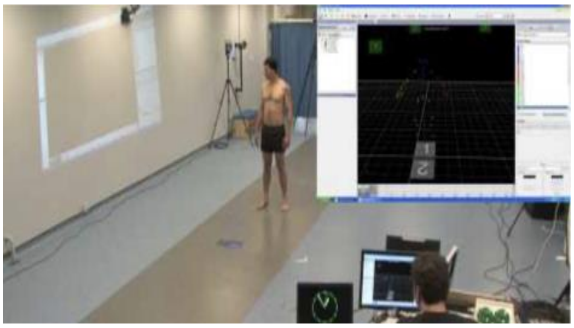

Figure 4 Vicon Application and Software Interface

However, compared to its beneficial use in the game industry, it has not yet been adequately addressed in academic studies.

Both Vicon and VR Tracker (2016) offer a tracking system that can operate wirelessly as well over a Wi-Fi connection, developed by the same software company, is also used in game research [28], Oculus VR's Constellation (2015) is also regarded as a tracking solution for Oculus Rift apparatus as seen in Figure 4 [29]. Yet some researchers, such as Durbin, states this system as 'low quality' [30].

PlayStation VR (2016), which has a similar operating pattern, also includes two camera bars to observe blue light strips on the headset and luminous spheres on Play Station Virtual Reality controllers [31] as seen on Figure 5.

The Lighthouse (2015) system, developed by Valve, is mainly developed for SteamVR and the HTC Vive, which was used for the experiment referred as a supplement as part of their study [32].

This type of monitoring structure is often 'erroneously' classified as outside-in monitoring in the literature [15]. Because in fact, this the setup utilizes two "base stations", which are boxes emitting infrared signals. The tracking process is performed by the device internally, moving from the inside to the outside.

Figure 5 Oculus Constellation Set

In 2019, HTC Vive Cosmos, which eschews the Lighthouse tracking system but has internal-external tracking, begins to be used. The headset has six built-in sensors, four on the front and one on each side, to scan forward, top, and bottom [32]. According to Machkovech, Lighthouse "promises backward compatibility" [33] for 2021, [34]; however, as of today, in December 2023, it is still not been examined [20].

In 2019, Facebook develops a tracking system called Insight integrated in conjunction with Oculus Quest from 2019, Oculus from 2020 and Oculus Rift S from 2019 [35], the built-in cameras produce a 3D representation of the room as seen on Figure 6 below.

Figure 6 Oculus Rift integration with Facebook

The IMU (Inertial Measurement Unit) system monitors movements of the head and hands, and the controllers are equipped with infrared LEDs to enhance the precision of controller tracking [36]. In a way, this can also be interpreted as the proliferation of highly sensitive devices to interpret human movement (related to the ability to integrate with Facebook-derived software).

In 2016, Lyrobotix reports that it was working on NOLO, a system incorporating both acoustic and optical tracking methods has been described by Lang (2016). Given its design as a sphere that links to the headset, this system can be employed with various VR glasses. The supplied transmitter emits ultrasonic and laser signals throughout the room, interacting with a sphere equipped with receivers. The system then processes the signals and calculates the user's position. This system does not appear very often in the literature on game studies, but according to Lang; "the contribution of this system to the developments after it is undeniable" [37].

The variety of different approaches to intensifying the gaming experience shows that it is important to further develop the immersion and fluidity of virtual reality. According to Novacek; "facilitating the player to move organically within the virtual world is of paramount importance" [15]. The fact that player is not restricted in any way, without having to wear some extra hardware on his head, on the screen, or whatever feels like an add-on [19], undoubtedly affects the experience [37].

In addition to systems that work from outside to inside, it is apparent that systems that cover the entire body, hands and feet are also becoming widespread. In their study "Synchronizing Data from Multiple Optical Sensors for Precise Hand Tracking", Novacek and Jirina assert that "hand-based systems in particular dominate our working styles and that this trend does not seem to change in the near future" [15].

Nicole Murchinson and Robert Proctor in their 2013 assertion [38], Spatial Compatibility Effects with Unimanual and Bimanual Wheel-Rotation Responses: An Homage to Guiard (1983); refer to Yves Guiard's 1983 theory. Accordingly, to deliver a completely immersive experience, the development of hand-based systems seems likely to be completed. However, manually operated systems are still relevant today and "will be relevant for a long time to come, because the hands are our primary tool" It is obvious that our hands are the main means of interaction. [38].

However, according to Miriam Karam, "not every approach is sufficient for every application [39]. In a virtual environment, a simple stick-shaped controller suffices to create the sensation of wielding a sword, where precision to the centimeter is not crucial when slaying a dragon. However, in a virtual scenario where one takes on the role of a surgeon conducting a heart transplant, every millimeter becomes critical as it can determine the outcome between life and death [39].

The concept of sensitivity, which directly influences the sense of presence and embodiment, is not the sole crucial aspect of hand-based interaction. Novacek and Jirina, in their study titled "Synchronizing Data from Multiple Optical Sensors for Precise Hand Tracking", interpret this as follows: "the input from the device not only enhances immersion and realism but also plays a crucial role in determining the application's outcome" [15]. For instance, delivering haptic feedback is essential for the development of medical devices that empower doctors to perform surgical procedures through an interface linked to a physical device. Without precise and prompt haptic response, performing various procedures becomes challenging for doctors [9]. Of course, this application in gaming experience might be a tad different.

HIRO's developers, Endo, Kawasaki, Mouri, Ishigure, Shimomura, Matsumura, and Koketsu, describe the system that "resemble basic controls such as a keyboard, mouse, or joystick, which are commonly employed in non-VR applications, or devices like 1994's PHANTOM [40] or HIRO from 2011 [41] are utilized to govern the virtual environment created for VR. However, they offer a limited sense of immersion to users due to their inability to provide unrestricted movement yet "to create real-life-like structures with real modules" [42]. And there are apparent attempts to copy the physical keyboard into a hybrid virtual environment. In her 2006 dissertation, Maria Karam describes these physical systems as they serve as the primary type of handheld controllers for virtual reality, given their close resemblance to input devices used in the past. Simultaneously, "interaction using the human hand has proven to be the most intuitive compared to any other organ". Slightly more advanced controllers provide haptic feedback [39].

Regarding the user's interaction and communication with an object in the virtual world, Chen, Chossat, and Shull note that "when the user touches a wall, for example" it may provide certain cues. They further explain that "the controller's vibrations provide the most common and simplest form of feedback. More complex feedback can be achieved by force feedback of only parts of the controller in one direction" [43].

Certain handheld devices also seek to guide users' motions, signaling when the next movement should occur or providing movement feedback based on physiological cues. However, these features are not widespread, and they are typically not used for managing the surroundings; instead, they solely offer response [44]. Examining this scenario within the broader context of holistic interaction, it becomes apparent that these capabilities may be deemed 'insufficient' to address the issue. Single-handed haptic controllers typically take the form of a wand, providing users with a straightforward means of controlling the virtual environment with one hand. While user-friendly, these devices, although more natural for many actions, fall short in supporting more intricate interactions as users cannot engage both hands simultaneously [45].

Most one-handed controllers are designed for basic tasks such as pointing, object selection, or teleportation within a virtual environment. In 2018 CLAW, which was created through collaboration with Stanford University and Microsoft Research Lab, provides three unique interaction modes: grasping virtual objects, touching virtual surfaces, and initiating actions [46]. Changes the corresponding haptic display based on how the user holds the controller as seen on figure 7.

Figure 7 CLAW

Additional haptic feedback methods include vibrations and force feedback, resembling the sensation of wielding a weapon in 2018, Choi et al. presented their research on this structure at the CHI - Human Factors in Computing System Conference [46]. Although it can be considered a limitation that it is designed only for the right hand, it is indubitably a convincing step for technologies that cover the whole body and promise more complete and enveloping weapons.

As a matter of fact, in 2018, Microsoft developed another controller in partnership with the University of Washington, the project was named Haptic Revolver [47]. In this multi-purpose system, it allows for touching, cutting, texture and shape creation through a rotating wheel with various surfaces on its side. As an illustration, the user can perceive distinct sensations for a table and a poker chip on the table. Nevertheless, this setup, while somewhat distant from replicating real-life textures, could be seen as potentially impacting the immersion. Rotating the wheel allows the user to sense it gliding on the surface. The surfaces can be reconfigured by altering the wheel, and a solitary thumb button [47] is employed for making selections.

Haptic controllers such as the VR Gun Controller from 2019, on the other hand, are in the form of weapons, closer to the game and real-world matching, and are widely used in the game industry [48]. And it even promises a more natural match with the 2020 improved version [49]. Jean-Marc and Bernatchez in "A study on the impact of spatial frames of reference on human performance in virtual reality user interfaces", suggest that effort and interaction during play, just like exercise, are distributed in both hands. Moreover, in their "Impact of Spatial Reference Frames on Human Performance in Virtual Reality User Interfaces" study, they recognize whether the player's interaction takes advantage of the enhanced feedback offered by leveraging the individual's proprioceptive sense to facilitate a more seamless and faster interaction compared to a device that is used only with one hand [50]. This is undoubtedly a promising approach for immersive holistic experiences. According to Steam gaming platform data, "the most utilized for gaming experience could be HTC's Vive device [51]. The device's vibrations provide tactile feedback and can be used with one hand when necessary.

Microsoft has Windows Mixed Reality Motion Controller (2017), and HoloLens Clicker (2016) (Figure 8), which are like the Oculus Touch system [21].

Figure 8 HoloLens Clicker

The more recent Etee (2020), the controller without buttons, utilizes proximity sensors to detect finger movements (Figure 9) and can consequently replicate complete finger movement in the virtual environment (Lin, 2020). Input is accomplished solely through touch, movement, force, and the closeness of the finger to the controller, as depicted in the figure 9. In a way, it can be considered as one of the systems closest to real life experience.

Figure 9 Etee Screen

Finch Shift from 2017 interfaces the player with separate bands (FinchTrackers) on player's arms [53]. Greenwald describes this structure as follows: "It combines information from the IMU units in the gloves, armbands, and headset mutually determine each other's positions, enabling the provision of 6 degrees of freedom (DOF) without the need for an additional external sensor [54]. Temoche, Ramirez and Rodrigez also generally interpret the fact that it includes wearable hand tracking systems, equipped with an array of sensors to "determine the position and bending of the hands and finger" are regarded as a 'technological acceleration' that brings virtual reality closest to a realistic sensation [55]. As noted by Li et al., "recognition accuracy is high because hands and fingers are directly tracked. However, wearable hand tracking systems are generally more expensive due to the complex technology used and the need for frequent calibration" [13]. Wearable devices are divided into various sections and groups, but this is beyond the scope of the research. The group including the examples we have examined in this section; the approach that is 'useful for game research but not very common for the industry' is those that use "microfluidic processing or image processing" [56].

With the demanding trend of to be able to 'wear' the controller on the body, handheld technologies distinguish themselves by incorporating systems that include a set of sensors capable of determining the finger and hand positioning, along with their degree of flexion [55], [15]. Earliest example of haptic gloves recognized is VPL Data Glove that conveys information about hand movements to the computer system. In From DataGlove to DataSuit, Lasko-Harvill et al. [57] writes about the tracking system called Polhemus that supports the tracking systems for the haptic.

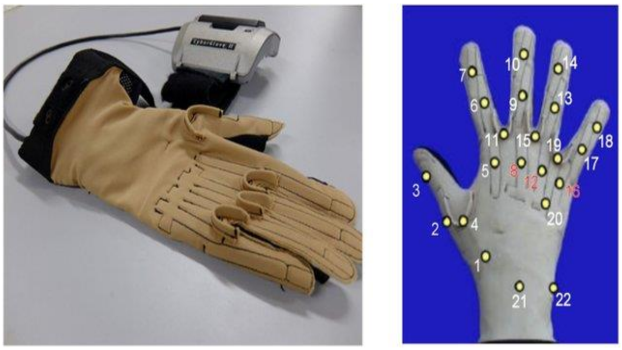

Figure 10 Cyber glove II

Contemporary CyberGlove Systems have been active since the 1990s and their project called Cyber Glove Series have been examined and analyzed in a "comprehensive calibrated database of kinematics for hand movements and grasps" by Jarque-Bou et al. in 2020 [58]. As seen above in Figure 10, Cyberglove II and the positioning of the 22 sensors.

MANUS Machinae was founded in 2014 in Netherland and the first prototype Data Glove was successfully built. In 2017 they developed their first Development Kit Gloves DK1 and DK2 and in 2020 the company released the Prime II Gloves.

Alongside with a dedicated Xsens Glove by MANUS and subsequently the Prime X series gloves makes Polygon free to use for the creative community. And recently in 2022 the new gold standard Quantum Metagloves seems to be leading the market [59] in the near future.

Although there are examples of research on the interaction of head and facial expressions other than hands [60], there are almost no concrete reports on the contribution of the player to the experience of immersion and presence in the game, as it is currently seems, as in the development phase 'for the game field'. When we aim for physical and holistic participation in the sake of embodiment and complete presence, it is not enough for users to use only their hands and feet to provide a great immersion in the virtual world. The attempt to involve the whole body not only takes the immersion and embodiment the virtual world to another level, but also opens the way for research that seeks to find numerical values in terms of tracking. Another important feature of whole-body systems is the possibility of providing tactile encompassing the entire body; so that the player can perceive when kicking a sack or being shot, to illustrate [61].

According to Erin Martel and Kasia Muldner, with comprehensive internal medicine integrated into the virtual world, another facet involves leveraging the user's physical functions with the body already equipped with sensors, it can also monitor the user's heart rate, perspiration, or electrical conductivity through their skin. This information could provide valuable insights into their fatigue levels or the level of enjoyment in the virtual world [62]. This approach allows for a more thorough and health-conscious evaluation of immersion and selected technologies.

One of the first 'tactile' suits that allowed control of the whole body while participating in the experience at the same time was the VPL DataSuit (1988), [57], seen in Figure 11 below.

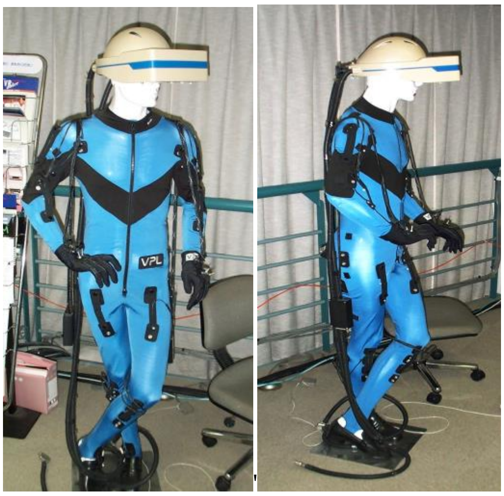

Figure 11 VPL Data Suit

The more recent HoloSuit Pro from 2018 and HoloSuit from 2020 are considered among the easiest to access and the earliest haptic suits that involves the whole body and parts of the body, available to the populace, not solely restricted to researchers. Besides its availability for use in sports, health, education, entertainment or industrial activities, there are almost no experiments in academic research [62]. And in the literature, various devices from the TactSuit (2017), [63] series of the tebHaptic company are also found [62].

Created specifically for the audio-based game Rez Infinite, Synesthesia Suit (2015) and (2020) provide not only vibratory feedback, but also game-appropriate sounds and colors; differing from its derivatives by combining image, sound, touch and promising something that did not exist until the 2020s.

Another example is Hardlight Suit (2016) and Sinko (2017), developed by NullSpace VR, has some updated features but goes bankrupt later in 2018 [15].

The creators of the HighFidelity VR [64] platform created the Exoskin haptic jacket [65] in collaboration with NeoSensory a technology manufacturer [66], [67]. It was launched in 2018 but today, in November 2023, no information about the product is available [68]. That same year, Disney designed a preliminary version of a haptic jacket with pneumatic actuation jacket known as the ForceJacket in partnership with Carnegie Mellon University and Massachusetts Institute of Technology [69].

DeLazio et al. states that; “this commodity is designed for specific gaming applications and has been officially launched in the market” [69]. While, University of Bristol researchers, defines this approach as “flawed” [70]. The alternative Frozen Suit provides and enhances haptic feedback with stiffness patches that can prevent the movement of certain parts of the player’s body in the intended direction, that they claim is the best example of this system of the time [70].

Introduced by a Pakistani company Haptika in 2015, Haptika Vest also makes players feel the warmth of the virtual environment, is one of the technologies that we encounter in the literature [71] however, not a trace can be found about, today in 2023. It may be appropriate to say that this type of approach aims for a more comfortable, natural and holistic immersion and complete embodiment experience that supports movements, includes other senses, and can be added to daily clothing without wearing any extra clothing or devices. Likewise, Perception Neuron Pro from 2019, [72] involves IMU sensors called several interconnected neurons positioned on the player’s body. The more neurons used, the more precise the experience will be. However, this comes at the expense of the fluidity of the in-game dynamics, as motion devices seem far from providing the real-life feeling of walking.

Human and movement are inseparable, and if the goal is the closest experience to reality, one should start with walking and jogging, which are among the most basic human movements. Naturally, the primary categories of movement devices fall into two types of treadmills—linear treadmill and omnidirectional treadmill. Additionally, there are devices without treadmills, such as motorized devices, user-operated devices, or pure walking.

However, incorporating sensors into such a system can be highly crucial. As Haruo Noma points out, ‘directly detecting and synchronizing’ [73] with walking speed is quite challenging, and a mechanical delay cannot be ruled out. Therefore, “the system must find a way to adjust the belt speed by using the user's position and walking speed as a reference” [73]. According to Campos and Bültoff, an alternative method for translating the player’s actual movement into the virtual environment involves the use of versatile treadmills [74]. These systems identify and offset the user’s walking movements, ensuring the user remains stationary regardless of the direction and speed of their movement, achieved through the counter movement of the device. For instance, according to Guizzo [75], “CyberWalk from 2018, could involve a belt-based treadmill or conveyor roller” [74].

CyberWalk [76] developed by German researchers at the Max Planck Institute for Biological Cybernetics has been essentially designed as a series of synchronized linear belts moving in one direction, enabling the player to enjoy greater freedom of movement compared to other platforms [75].

Campos and Bültoff discuss that “the drawback of the mechanism” [74] is when the user walks forward and stops, the treadmill continues to resist their movement, resulting in the user coming to a stop behind the center. One of the common aspects of these systems, each one follows the other and is more advanced than the previous one, can be considered as “the user moves his body even if he does not move on his own” [77]. Another example is the recent Infinadeck.

KAT Walk [78] supports different bodily functions and has smattering versions; KAT VR, KAT VR Premium and KAT VR Mini of 2016, 2017 and 2918 as seen below in Figure 12 and later in 2019 an advanced version KAT Loco.

Figure 12 KAT VR Walk

Its innovative design utilizes a mechanical arm and harness to support the player’s weight, rather than relying on a ring and multiple legs for stability [78]. The unique design involves the body being aided by a mechanical handle equipped with a harness capable of bearing their weight, as opposed to being suspended by a ring supported by multiple legs. Enough pressure is lacking from the strap for the wearer to feel uncomfortable because they are not hanging from it; rather, they are merely supported by it. In the virtual environment, users can run, crouch, jump, walk backwards, and walk. The action does not rely on a low-friction pad as it might make users feel unstable. Instead, it utilizes a surface made of high-traction material with consistent utilizing rolling friction to replicate genuine walking sensations.

While the most functional and promising discourse is seemed to be walking or running, for specific activities such as cycling or flying there will supposedly have to be specific devices that are designed for the specific activity VR Bike [79] not for gaming but for fitness-game purposes.

To summarize; not only for academic purposes or embodiment researchers in gaming but alternate reality labs, but also by business-oriented companies as well, develops and benefits from haptic controllers. The previous sections discuss the systems found in the literature and used as experimental research elements.

The earliest findings dates back to 1980s and literature suggests to refer to several articles such as; “Overview of Controllers of User Interface for Virtual Reality” [15], “Gesture Interaction in Virtual Reality; Virtual Reality and Intelligent Hardware” [13], “VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques” [80], “Touching Virtual Reality: A Review of Haptic Gloves” [12], “Review of Three-Dimensional Human-Computer Interaction with Focus on the Leap Motion Controller” [42], “Approaches and Applications of Virtual Reality and Gesture Recognition: A Review” [10], “Visualizing the Keyboard in Virtual Reality for Enhancing Immersive Experience” [81] and “A Study on the Impact of Spatial Frames of Reference on Human Performance in Virtual Reality User Interfaces” [8]. Amongst the literary works, Novacek and Jirina’s research [15] can be considered as the most meticulously tailored yet not as summarized as ours and aimed specifically embodiment in Virtual Reality and Augmented Reality experiences.

5. Conclusion

Virtual reality technologies, along with game world and experience design, are on the rise at a rapid pace, and it is impossible to say which approach will prevail. However, the promise of such technologies is that they will affect important notions such as being ‘embodied’ in the virtual or augmented world, existing, and being surrounded. For instance, in the case of Kinect Star Wars, which holds 55 points from Metascore (accompanied by user rating of 3.6 out of

10), critiques highlight that nothing feels natural in the game. The movements, whether running, fighting, flying, or shooting, are described as ‘subpar and extremely awkward’. The game is criticized for having a mechanical feel [18]. Another case in the study of Cohen et. al., similarly, reveals that “fighting is less fun than it should be, full of awkward, clumsy arm swings that don’t make you feel like you’re actually controlling the lightsaber” [82] thus it is clear that the controllers and devices we have discussed so far try to achieve a holistic approach in the process.

On the other hand, there are also studies that show that the feeling of immersion and embodiment is much higher when experienced only with a keyboard or mouse, without being experienced with the state-of-the-art intermediaries we have discussed here. So, can we experience the state of being surrounded and being present, which are ‘internal’ phenomena, directly and only with an ‘external’ effect through devices with more natural matches? The question would lead us to exceed the main scope of this paper but suggesting that future and ongoing research.

This paper investigates the literature on wearable technologies, haptic controllers that interfaces between the virtual and augmented realms and player. Numerous advances and brand-new technologies will arrive but by examining in depth the phenomena of interaction, participation and integration, embodiment, and presence, will presumedly provide insights to the question its depth, structure, evaluation and measurements and boundaries.

Acknowledgement

This present article was reproduced from the PhD thesis of the corresponding author Burçin Geniş-Ergün under the advisory of Prof. Dr. Rıfat Şahiner, titled *“Immersion and Presence in Digital Games Through Merleau-Ponty’s Phenomenology of Perception”* at Yıldız Technical University, Art and Design Program, Istanbul, Türkiye.

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