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OpenAI ChatGPT Generated Literature Review: Digital Twin in Healthcare

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Abstract— **Literature review articles are essential to summarize the related work in the selected field. However, covering all related studies takes too much time and effort. This study questions how Artificial Intelligence can be used in this process. We used ChatGPT to create a literature review article to show the stage of the OpenAI ChatGPT artificial intelligence application. As the subject, the applications of Digital Twin in the health field were chosen. Abstracts of the last three years (2020, 2021 and 2022) papers were obtained from the keyword "Digital twin in healthcare" search results on Google Scholar and paraphrased by ChatGPT. Later on, we asked ChatGPT questions. The results are promising; however, the paraphrased parts had significant matches when checked with the Ithenticate tool. This article is the first attempt to show the compilation and expression of knowledge will be accelerated with the help of artificial intelligence. We are still at the beginning of such advances. The future academic publishing process will require less human effort, which in turn will allow academics to focus on their studies. In future studies, we will monitor citations to this study to evaluate the academic validity of the content produced by the ChatGPT.**

Keywords— OpenAI, ChatGPT, Artificial Intelligence, Digital twin, Healthcare, ChatGPT revolution, Academic Publishing

I. Introduction

OpenAI ChatGPT [1] is a chatbot based on the OpenAI GPT-3 language model. It is designed to generate human-like text responses to user input in a conversational context. OpenAI ChatGPT is trained on a large dataset of human conversations and can be used to create responses to a wide range of topics and prompts. The chatbot can be used for customer service, content creation, and language translation tasks, creating replies in multiple languages. OpenAI ChatGPT is available through the OpenAI API, which allows developers to access and integrate the chatbot into their applications and systems.

OpenAI ChatGPT is a variant of the GPT (Generative Pre-trained Transformer) language model developed by OpenAI. It is designed to generate human-like text, allowing it to engage in conversation with users naturally and intuitively. OpenAI ChatGPT is trained on a large dataset of human conversations, allowing it to understand and respond to a wide range of topics and contexts. It can be used in various applications, such as chatbots, customer service agents, and language translation systems. OpenAI ChatGPT is a state-of-the-art language model able to generate coherent and natural text that can be indistinguishable from text written by a human.

As an artificial intelligence, ChatGPT may need help to change academic writing practices. However, it can provide information and guidance on ways to improve people's academic writing skills. People can improve the quality of their academic writing and effectively communicate their ideas to readers by following the following few tips:

- Understand the purpose of people's writing: Is it to inform, persuade, or analyse? Identifying the goal will help them choose the appropriate tone, style, and structure for their writing.
- Use clear and concise language: Avoid jargon and use simple, straightforward language to convey your ideas effectively.
- Use evidence to support their claims: It is essential to provide evidence to support your ideas and arguments in academic writing. Use credible sources and provide proper citations to support their claims.
- Use proper structure: Organise their writing into clear sections and use headings and subheadings to guide the reader through their argument.
- Edit and proofread: Make sure to proofread their writing for grammar and spelling errors and edit for clarity and concision.

Artificial intelligence (AI) is a technological development that will significantly impact daily life and legal regulations, including civil, criminal, and liability laws. One area where AI will affect is the regulation of intellectual property rights. There is a question of who should own patents for inventions made by AI machines [2]. Who owns the AI- generated articles? Is it the person who asks the information and questions necessary to write the essay, or is it the software and machine that creates this content? These and many other questions need to be answered.

In this study, it is evaluated whether an academic article can be created by AI and whether the created article carries values such as academic content and originality. All content except the "Abstract", "Introduction", "Method", "Findings and Results" and "Discussion and Conclusion" subsections was generated by ChatGPT. Another purpose of this study is to analyse the number of citations this article will receive and the characteristics of the citations. When the required sample size for the citations is reached (at least 100 journal article citations), we will examine the studies referring to this article and the effectiveness, and academic validity of the paper will be interpreted through citations.

In the first following section, used methods are given. In the second section one of the new technologies Digital Twin was defined by ChatGPT. In the third section, information about the use and features of Digital Twin in HealthCare is shared by ChatGPT. In the fourth part, the abstracts of the articles that were found as a result of the search for "Digital Twin in Healthcare" and that could be accessed via Google Scholar belonging the last 3 years were paraphrased by ChatGPT. In the fifth section, the findings and results are given. Finally, the study ends with the evaluations made by us under the title of Discussion and Conclusion.

II. Method

It is useful to reiterate the aim of doing this study here. ChatGPT is an important example of how artificial intelligence can produce results in academic article writing. Therefore, we aim to ensure that a review article is written by artificial intelligence at a basic level and to question its academic validity. For this purpose, as a research method, it was determined that the abstracts of the results obtained by searching on a topic (Digital Twin in Healthcare) that we determined on Google Scholar should be paraphrased with ChatGPT. Also, "What is Digital Twin?" and "Digital Twin in Healthcare" was queried to ChatGPT to generate for the Digital Twin and Healthcare topics. These two titles are included in the article before the literature title.

The texts created by ChatGPT by paraphrasing and the texts produced by giving the answers are checked by plagiarism tools such as Ithenticate, intihal.net and alike. As a result of the evaluation, an evaluation is made on the similarity rate with the previous studies.

In order to evaluate the Academic Validity of this study, the following method was determined. This article has been published on the preprint sharing environments (SSRN, Arxiv, Techxriv, Researchgate, Academia etc.). Citations to this study will be recorded then. Finally, these articles will be reviewed and evaluated when the citations reach a certain number (for example, 100 journal article citations). The academic validity of this text produced by ChatGPT will be evaluated from the criticisms and evaluations in these citations.

III. Digital Twin

A digital twin is a digital representation of a physical object or system that allows for the simulation of the object or system's behaviour, performance, and characteristics. This technology has the potential to revolutionize a wide range of industries, from manufacturing and logistics to healthcare and urban planning.

The concept of a digital twin originated in the manufacturing industry, where it was used to optimize the design and operation of complex systems such as aircraft engines and industrial machinery. Today, digital twins are being applied to a much more comprehensive range of applications, including infrastructure, buildings, and even entire cities.

One of the key benefits of digital twins is their ability to provide real-time data and insights into the performance and behaviour of a physical object or system. These insights allow for the identification of problems and inefficiencies in real-time, enabling proactive maintenance and optimization of the system.

In manufacturing, we can use digital twins to optimize production, reduce downtime, and improve efficiency. For example, a digital twin of a factory floor can be used to simulate and optimize the flow of materials, identify bottlenecks, and minimize waste.

In healthcare, we can use digital twins to simulate and optimize patient care pathways, reducing the risk of medical errors and improving outcomes. We can also use digital twins to optimize the design and operation of healthcare facilities, such as hospitals and clinics.

In urban planning, we can use digital twins to simulate and optimize the design and operation of entire cities, including transportation systems, energy networks, and public services. These optimizations can help cities to become more efficient, sustainable, and liveable.

Overall, digital twins have the potential to transform a wide range of industries and applications by providing real-time data and insights that can be used to optimize the performance and behaviour of physical objects and systems. As technology advances, digital twins will likely become increasingly prevalent in many sectors.

IV. Digital Twin in Healthcare

Digital twins have the potential to revolutionize healthcare by providing real-time data and insights that can be used to optimize patient care pathways and improve outcomes. Several key themes emerge in a review of the literature on digital twins in healthcare.

One of the main benefits of digital twins in healthcare is their ability to provide real-time data and insights into patient care. By simulating and optimizing patient care pathways, digital twins can help to reduce the risk of medical errors and improve patient outcomes. For example, a digital twin of a patient's medical history and current condition can be used to identify potential problems and inefficiencies in the care process, enabling proactive intervention and optimization of care.

Another key benefit of digital twins in healthcare is their ability to support remote monitoring and telemedicine. By providing real-time data on patient vital signs and other health indicators, digital twins can enable healthcare providers to monitor patients remotely and provide care remotely, reducing the need for in-person visits and improving access to care.

We can also use digital twins to optimize the design and operation of healthcare facilities, such as hospitals and clinics. By simulating and optimizing the flow of patients, staff, and resources within a facility, digital twins can help to improve efficiency, reduce wait times, and improve patient satisfaction.

Overall, using digital twins in healthcare can transform the way healthcare is delivered, enabling more personalized, efficient, and effective care. As technology advances, digital twins will likely become increasingly prevalent in healthcare, providing valuable data and insights that can be used to optimize patient care and improve outcomes.

V. Literature Review

There has been a significant increase in the use of digital healthcare services, such as personalized medicine, telemedicine, and smart diet management, in recent years. These services often have diverse requirements, and require intelligent analytics and self-sustaining networks in order to function effectively. Digital twins can help to enable proactive, intelligent analytics and self-sustaining networks in healthcare, allowing for the efficient management of resources and minimum interaction from end-users or network operators. In this article, we provide an overview of digital twins in healthcare, including a proposed architecture and several use cases. We also identify open research challenges and potential solutions.

The proposed digital twin-based system for monitoring COVID-19 symptoms uses mobile phones to collect data, which is fed into a digital copy of each individual stored in the cloud. This digital twin is continually updated with real-time measurements from sensors and other devices, and is analyzed using machine learning and artificial intelligence techniques to determine the individual's health status. The system also utilizes blockchain technology to ensure the confidentiality of the data, which can be shared for research purposes with the consent of the individual. The goal of the system is to provide early diagnosis and prevent the spread of the disease by establishing a protocol for following up with patients and those at risk [3].

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality from non- communicable diseases worldwide. In many cases, effective acute care and risk factor management strategies based on data from epidemiological studies and clinical trials have improved survival and quality of life. However, approximately half of all myocardial infarction and stroke events occur in patients who do not meet the criteria for cholesterol-lowering treatment, and costly preventive therapies with potential side effects may be given unnecessarily. Improving outcomes in cardiology therefore requires a better understanding of individual susceptibility and prognosis [4].

Data-driven approaches to risk assessment and treatment are central to the goals of precision medicine, which aims to disrupt traditional healthcare practices by providing early, customized therapy that considers molecular, genetic, physical, and environmental data profiles. While prediction and personalization have always been a part of medicine, the convergence of 21st century technologies with advances in biomedicine is enabling the consolidation and analysis of large amounts of data from a wide range of sources using massive data networks. Improvements in clinical data capture, imaging, and molecular phenotyping also contribute to the goal of precision medicine. The ability to process large data sets digitally has greatly enhanced the utility of this data [4].

The health digital twin builds on these capabilities by using a virtual replica to receive a patient's molecular, physiological, and lifestyle data, allowing for risk prediction and personalized treatment for the real-life patient. Artificial intelligence helps link the cyber, physical, and data domains to create virtual models by using technologies such as cloud computing, big data processing, machine learning, and pattern recognition to mimic human reasoning. These core technologies can also assist in decision-making for a patient by synthesizing data from multiple real-world sources within a virtual domain. Digital twins can be created at various levels, including the whole body, a single organ, or the cellular level, and can be used to study specific conditions or settings, such as cancer or critical care. An individual's digital twin can be copied and tested with different treatments to determine the optimal intervention. By aggregating digital twins from many individuals with diverse genetic, biomedical, and lifestyle profiles, a population-based database can be created, which can be used for data-driven prevention and patient matching for clinical trials conducted in silico as an alternative to lengthy or costly animal and human studies [4].

In a paper by Volkow et al., it is noted that as the population grows, the need for high-quality medical services and the use of information technology in medicine also increases. The concept of Smart Healthcare aims to address the challenges faced in modern healthcare through various approaches, including the use of digital twins, the Internet of Things, and mobile medicine. The paper reviews the main problems in modern healthcare and analyses existing approaches and technologies in these areas. It also discusses the key features of modern platforms that support Mobile Health Applications. Based on this analysis, the authors propose the concept of a Smart Healthcare Platform, focused on supporting the development of Mobile Health Applications through the organization, management, and sharing of user data [5].

While Digital Twin technology has been applied in a variety of fields, including advanced manufacturing, Product Lifecycle Management (PLM), and smart healthcare, this paper discusses the potential use of Digital Twin for full lifecycle management of humans. The concept of an Augmented Digital Twin is introduced as the foundation for the concept of a Human Digital Twin (HDT), which is the central focus of the paper. Drawing on the experience of using Digital Twin in smart manufacturing, PLM, and smart healthcare, as well as the development of related technologies such as data mining, data fusion analysis, artificial intelligence, particularly deep learning, and human-computer science, it is concluded that HDT could be a useful approach to full lifecycle health management and that it is possible to construct a Human Digital Twin, particularly from a technological standpoint. A comparison between Digital Twin and Human Digital Twin demonstrates this possibility. The paper presents the concept, conceptual model, and characteristics of HDT to lay the groundwork for its construction. It also discusses how to construct a Human Digital Twin by proposing a Human Digital Twin System Architecture and Implementation Approach. However, it is noted that there are many challenges to overcome in this process, including extreme complexity and security and social ethics issues [6].

Personalized medicine involves using detailed information about individual people to identify deviations from the normal. Digital twins in engineering provide a framework for analysing these data-driven healthcare practices and their ethical and societal implications for therapy, preventative care, and human enhancement. Digital twins are pairs of individual physical artifacts and digital models that dynamically reflect the status of the artifacts. Ethical and societal implications of digital twins are examined, and it is noted that they have the potential to deliver significant societal benefits and function as a social equalizer by allowing for effective, equalizing enhancement interventions. Digital twins will be important for providing highly personalized treatments and interventions, and they rely on explainable artificial intelligence [7].

Anticipating the ethical impact of emerging technologies is an important aspect of responsible innovation, and the digital twin is one such technology that is emerging. A digital twin is a living replica of a physical system (human or non-human) that combines various emerging technologies such as artificial intelligence, the Internet of Things, big data, and robotics, each of which brings its own ethical issues. This report presents the results of a qualitative study on the ethical benefits and risks of using digital twins in healthcare. The study used insights from the ethics of technology and the Quadruple Helix theory of innovation, and included desk research of white literature and 23 interviews with representatives from industry, research, policy, and civil society. The results showed that digital twins have the potential to produce ethical benefits in areas such as the prevention and treatment of disease, cost reduction, patient autonomy and freedom, and equal treatment, but also have ethical risks in areas such as privacy and data property, disruption of existing societal structures, inequality, and injustice. The report concludes with a reflection on the analytical tool used and suggestions for further research [8].

In a paper by Elayan et al., it is noted that the use of digital technologies in the healthcare industry, known as digital and smart healthcare, has increased in recent years in an effort to improve patient care, increase life expectancy, and reduce healthcare costs. One such technology that has the potential to significantly impact the field is digital twin (DT) technology. DT is a virtual replica of a physical asset that reflects its current status through real- time data. The paper proposes and implements an intelligent context-aware healthcare system using DT technology. As part of this system, an electrocardiogram (ECG) heart rhythms classifier model was built using machine learning to diagnose heart disease and detect heart problems. The results showed that integrating DT with healthcare can improve the healthcare process by bringing patients and healthcare professionals together in an intelligent, comprehensive, and scalable health ecosystem. Additionally, the implementation of the ECG classifier demonstrated the potential for using machine learning and artificial intelligence with various human body metrics for continuous monitoring and abnormalities detection. The paper also found that neural network-based algorithms perform better on ECG data than traditional machine learning algorithms [9].

The Internet of Medical Things (IoMT) is becoming increasingly prevalent, with the widespread use of smart medical devices and applications in smart hospitals, home healthcare, and nursing homes. It combines smart medical devices, cloud computing services, and core Internet of Things (IoT) technologies to monitor patients' vital signs, track health conditions, and generate multivariate data to support on-demand healthcare. Typically, this large amount of data is analyzed on centralized servers. However, anomaly detection (AD) in centralized healthcare systems can be slow and resource-intensive, and there are also privacy concerns related to sending patients' personal health data to a centralized server, which can also introduce security risks such as the possibility of data poisoning. To address these issues with centralized AD models, the authors propose a federated learning (FL)-based AD model that uses edge cloudlets to run AD models locally without sharing patients' data. While existing FL approaches perform aggregation on a single server, which limits their scope, they introduce a hierarchical FL approach that enables aggregation at different levels and multi-party collaboration. They also propose a novel disease-based grouping mechanism for organizing different AD models based on specific types of diseases. In addition, they develop a new Federated Time Distributed (FEDTIMEDIS) Long Short-Term Memory (LSTM) approach for training the AD model. They present a remote patient monitoring (RPM) use case to demonstrate our model and provide a proof-of-concept implementation using Digital Twin (DT) and edge cloudlets [10].

As the proportion of the aging population increases, the need for sustainable, high-quality, and timely healthcare services has become increasingly pressing, particularly in light of the COVID-19 pandemic in 2020. To meet this demand, a promising strategy is to introduce cloud computing and digital twin techniques into healthcare systems. In this approach, a cloud server is used to store healthcare data and provide efficient query services, while a digital twin is used to build a digital representation of a patient and leverage the query services of the cloud server to monitor the healthcare state of the patient. While several cloud computing and digital twin- based healthcare monitoring frameworks have been proposed, none have addressed data privacy concerns, even though the leakage of private healthcare information could have catastrophic consequences for patients. To address this challenge, this paper proposes an efficient and privacy-preserving similarity query-based healthcare monitoring scheme over a digital twin cloud platform, called PSim-DTH. The scheme employs a partition-based tree to index the healthcare data and uses matrix encryption to propose a privacy-preserving PB-tree-based similarity range query algorithm. Security analysis and performance evaluation are conducted, and the results show that the proposed PSim-DTH scheme is both privacy-preserving and efficient [11].

In the future, it is possible that a digital twin of each person's genetic profile will be created at birth. If someone becomes ill, this virtual representation of themselves could be treated with a vast number of drugs using computational methods to determine the most effective medication. The digital twin could also be used to predict which medical conditions a person may be at risk for, allowing them to take preventive measures to avoid major diseases before they occur [12].

The process of digitization and digitalization has already had a significant impact on our world, and further disruptions are expected as digital transformation continues, with digital twins playing a key role. As big data techniques, the Internet of Things, cloud computing, and artificial intelligence algorithms advance, digital twin technology is experiencing rapid development and has been identified as one of the top ten most promising technologies. Although it is still in its early stages, digital twins are already being widely used in various fields, particularly in industry, smart cities, and smart health, which are the areas that attract the most research. There are numerous articles and reviews on digital twins published every year in these three fields, making it timely and necessary to provide an analysis of the published work. This article aims to do just that, providing a survey of the major research and application areas of digital twins. It begins by analyzing the recent developments of digital twins, then summarizes the theoretical foundations of the technology, and concludes with specific developments in various application areas of digital twins. The article also discusses the challenges that may be encountered in the future [13].

Digital Twins (DTs) are becoming more widespread in various industries due to advances in computing power and data science. There are many sensors and connected devices that generate data, which can be used to create a digital model of a system or object and predict and simulate various scenarios. DTs have recently been adapted for use in the healthcare industry for accurate medical simulations and resource management, but the technology is still relatively new to the healthcare system and there are concerns about security threats. This paper proposes a Blockchain-based secure Digital Twin framework for a smart healthy city as a solution to these threats. The paper also discusses the current COVID-19 pandemic as a case study and suggests that DTs can be used to control the situation, prevent future cases, and personalize treatment [14].

De Maeyer and Markopoulos study how experts in the digital transformation of healthcare envision the use of Digital Twins. Digital Twins are digital replicas of physical assets, processes, people, places, systems, and devices that can be used for scientific experiments, simulations, and predictions of intervention outcomes. They are a new technology with different implications and possibilities for different applications, and may evolve in various ways. The authors used the Delphi method to reach a consensus among experts on three research questions related to the materialization, expectations, and implementation of Digital Twins in healthcare. The main conclusion is that Digital Twins are seen as a way to enable preventive healthcare and trial-and-error approaches to support personalized medicine and patient-centered care [15].

De Maeyer and Markopoulos explore how experts in the digital transformation of healthcare envision the use of digital twins (DTs), which are digital replicas of physical assets, processes, people, places, systems, and devices that can be used for scientific experiments, simulations, and prediction of intervention outcomes. DTs are a new and evolving technology, and can be applied in different ways and for different purposes. To understand how DTs might develop and impact healthcare, the authors conducted a Delphi study and survey with experts to reach a consensus on how DTs might be materialized, what expectations there are for their use, and how they might be implemented in healthcare. The study aimed to identify the top ranked topics for further consideration [16].

One of the thesis investigates the potential use of digital twins in the healthcare industry as a means of predicting and preventing diseases. It examines the values and perspectives of individuals towards the use of digital twins in diagnosis, and proposes different forms or concepts that a digital twin could take in order to be meaningful to the user. The research found that the meaningfulness of a digital twin may vary significantly based on factors such as age, life situation, preferences, and individual personality. It also found that the time, place, and frequency at which an individual interacts with a digital twin may be important considerations. The thesis concludes with guidelines for developing a more user-centered and meaningful digital twin that takes into account the varied and dynamic nature of user values [17].

BOATĂ and other's paper summarizes the progress made in using the concept of digital twins to select the most appropriate medication for an individual, based on genetic expressions related to a particular disease and the genes targeted by therapy. The paper presents a subnet model that predicts existing drugs for a specific pathology. Finally, the paper discusses how the proposed method could be used to search for a medication for the disease caused by the Covid-19 virus, referencing the results of clinical trials conducted after the start of the pandemic [18].

Digital twin technology, which creates virtual representations of people, products, or buildings, has the potential to revolutionize the healthcare industry by improving the diagnosis and treatment of patients, streamlining preventative care, and facilitating new approaches for hospital planning. In the future, it could be used to create a digital twin of each person's genetic profile at birth, allowing healthcare professionals to computationally test the most effective medications for an individual and predict their risk for certain medical conditions. This could enable more personalized and preventative healthcare approaches [19].

Madubuike and Anumba’s research aims to examine how digital twin technology can be used to improve healthcare facilities management. Currently, healthcare facilities management often relies on a reactive approach, where issues are only addressed when they arise. Digital twins, which are virtual representations of physical assets created using real-time data, can be used to monitor and manage critical healthcare facilities in a more preventive way. The research uses literature review and interviews to address its objectives and identify issues with critical healthcare facilities that can be addressed using digital twin technology. It also reviews the technologies that enable digital twins and presents a system architecture for their use in healthcare facilities management. The research concludes by discussing the potential benefits of using digital twins in healthcare facilities management [20].

Voigt et al. discuss the potential for digital twins to improve the management of multiple sclerosis (MS) by providing an individualized, innovative approach to disease management. They propose that digital twins, which are virtual representations of a patient's characteristics created using artificial intelligence-based analysis of various disease parameters, could help healthcare professionals handle large amounts of patient data and provide more personalized, effective care by integrating data from multiple sources, implementing individualized clinical pathways, and facilitating communication and shared decision-making between patients and physicians. The authors also discuss the potential benefits of using digital twins in MS management, including improved diagnosis, monitoring, and therapy, enhanced patient well- being, reduced economic costs, and prevention of disease progression. They argue that digital twins can help make precision medicine and patient-centered care a reality in everyday practice [21].

A digital twin is a virtual representation of a real-life object or system that is connected to its physical counterpart in a way that allows for real-time data exchange and analysis. Digital twins are being used in various industries, and when applied to the fields of healthcare and public health, they have the potential to revolutionize traditional electronic health records by making them more precise and accurate. This technology allows for learning, hypothesis testing, and in silico experiments, and has the potential to enable highly personalized treatments and interventions in the future. This paper discusses the history and main concepts of digital twins, provides examples of their use in personal medicine, public health, and smart cities, and explores the technical and ethical challenges involved in their application [22].

Hussain et al. aims to demonstrate the use of a digital twin in healthcare, specifically for stroke patients, using EEG data and machine learning techniques. The authors collected EEG data from 48 stroke patients and 75 healthy individuals using portable EEG devices and analyzed the data to identify characteristics that could be used to distinguish between the two groups. They found that certain brain activity measurements were useful for classifying stroke patients and healthy individuals in different mental states, and used a machine learning model (SVM) to classify the data with 76% accuracy. The authors suggest that this digital twin framework could be used to help make clinical decisions related to stroke prevention and post-stroke treatment [23].

Healthcare technologies have seen increased use during the COVID-19 pandemic, including remote patient care and virtual follow-up. These technologies are likely to continue to be adapted in the future, both as a way to prepare for future pandemics and due to the advancement of artificial intelligence. This study looks at the potential healthcare applications of digital twin technology, which involves creating a virtual counterpart to a physical model and studying the relationship between the two. It is proposed that digital twin technology could be used to analyze the relationship between a physical cancer patient and their corresponding digital twin in order to predict and prevent neurological complications related to the disease. This approach is based on the idea that data science can be used to inform the diagnosis, treatment planning, and prognosis of cancer care. Digital twin technology could be used in precision medicine, cancer care and treatment modeling, predictive analytics and machine learning, and to bring together different perspectives from clinicians [24].

In a paper by Alazab et al., it is noted that the landscape of digital healthcare, also known as Healthcare 4.0, has seen a significant increase in services such as personalized healthcare, intelligent rehabilitation, telemedicine, and smart diet management. These services have diverse requirements that need to be met through proactive intelligent analytics and self-sustaining networks. Proactive intelligent analytics allows for the efficient management of resources in response to user requests, while self-sustaining networks operate with minimal interaction from end-users or network operators. To enable Healthcare 4.0 with these capabilities, digital twins can be utilized. The paper provides an overview and recent advancements in the use of digital twins for Healthcare 4.0, presents an architecture for digital twins in healthcare, and discusses several use cases. Additionally, the paper identifies open research challenges and possible solutions [25].

In recent years, Digital Twins technology has been introduced into the healthcare industry, bringing significant changes to the way medical care is provided. In this study, the authors propose a new disease diagnosis algorithm called the Factorization Machine Combine Product- based Neural Network (FMCPNN), which is an improved version of the Product-based Neural Network (PNN). PNN is an end-to-end Factorization Machine algorithm that is effective at handling sparse data, but it lacks the ability to handle low-order feature interactions, which can limit its generalization capabilities. FMCPNN adds a second-order interaction component to PNN, improving its performance. FMCPNN can be effectively used in Digital Twin medical systems to improve the accuracy and speed of disease diagnosis. Their tests have shown that FMCPNN outperforms some other advanced models [26].

Human digital twin (HDT) is a technology that has the potential to revolutionize the healthcare system by enabling personalized healthcare services (PHS) through the use of tools such as artificial intelligence and blockchain. Its implementation is expected to be similar to digital twins in other sectors, such as manufacturing and aviation, and will consist of three key dimensions: the physical entity, virtual model, and connection that characterizes the physical- virtual interactions. However, the complexity of the human body, with its constant molecular and physiological changes, makes it difficult to extract precise medical data and model HDTs. As a result, HDT is more complex than other types of digital twins and the methods for implementing it are not yet clear, which requires further investigation. This paper presents the architectural framework and key design requirements for HDT, discusses the key technologies and technical challenges, and suggests future directions for research. It is believed that this paper will stimulate new research efforts towards the development of HDT for PHS [27].

Emotion recognition (ER) in healthcare has gained significant attention due to recent advances in machine-learning and deep-learning techniques. ER systems, combined with digital twins of individuals in real-time, can facilitate the monitoring, understanding, and improvement of physical capabilities, as well as provide constant input to improve quality of life and well-being for personalized healthcare. However, building such ER systems in real-time presents technical challenges such as limited datasets, occlusion and lighting issues, identifying important features, false classification of emotions, and high implementation costs. To address these challenges, a simple, efficient, and adaptable ER system was developed that acquires and processes images in real-time using a web camera. An end-to-end framework was also proposed that combines an ER system with a digital twin setup, allowing for the prediction and testing of results prior to providing the best possible personal healthcare treatment. The proposed ER system achieved promising results in a shorter training time without sacrificing accuracy. It is expected that in real-time, the system will be useful in healthcare centres for monitoring patients' health conditions, early diagnosis of life-threatening diseases, and obtaining the most effective treatment for patients during emergencies [28].

The digital world has seen significant growth in recent decades, and the COVID-19 pandemic has further accelerated this trend. Digital transformations are affecting all aspects of our lives, and new technologies are constantly emerging and attracting attention and investment. Digital twin technology, which has gained significant popularity in recent years, is now being applied in the healthcare sector, which has been under scrutiny due to the COVID-19 pandemic. This paper aims to provide a better understanding of digital twin technology, address common misconceptions, and review the current state of digital twin applications in healthcare. It also summarizes the functions of digital twins at different stages of their use in the context of digital twin technology in healthcare. The paper proposes a model for using digital twin technology in healthcare based on the Internet of Things as a service concept and digital twinning as a service model supporting Industry 4.0. It also identifies different groups of physical entities that can be represented by digital twins in healthcare. The research discusses the value of digital twin technology in healthcare, as well as the current challenges and future research directions [29].

The concept of digital twins has the potential to transform the current healthcare system by making it more personalized. As a convergence of healthcare, artificial intelligence, and information and communication technologies, personalized healthcare services developed under the concept of digital twins raise a range of ethical issues. While some of these ethical issues are known to researchers in the field of digital health and personalized medicine, there is currently no comprehensive review that examines the major ethical risks of digital twins for personalized healthcare services. This study aims to address this gap by identifying the major ethical risks of digital twins for personalized healthcare services. A working definition of digital twins for personalized healthcare services is proposed, and a process-oriented ethical map is developed to identify the major ethical risks in each stage of data processing. A literature review of eHealth, personalized medicine, precision medicine, and information engineering is conducted to identify potential issues. The ethical map allows for the systematic identification of ethical concerns that emerge during the transformation of raw data into valuable information. Developers of digital twins for personalized healthcare services can use this map to proactively identify and address ethical risks during the development stage. This paper provides a working definition of digital twins for personalized healthcare services, identifies 10 major operational problems and the corresponding ethical risks, and suggests a process-oriented ethical map to assist in the analysis of ethical risks [30].

Digital twins (DTs) are playing a vital role in transforming the healthcare industry by enabling more personalized, intelligent, and proactive healthcare. With the evolution of personalized healthcare, there is a need to create a virtual replica for individuals to provide the right type of care in the right way and at the right time. In this paper, the concept of a personal digital twin (PDT) as an enhanced version of a DT with actionable insight capabilities is examined. PDT can bring value to patients by enabling more accurate decision-making and proper treatment selection and optimization. The progression of PDT as a revolutionary technology in healthcare research and industry is also explored. However, although there have been numerous research studies on the use of DTs in smart healthcare, PDT is still in its early stages. Therefore, this work aims to guide the design of industrial personalized healthcare systems by introducing a reference framework that brings together existing advanced technologies such as DTs, blockchain, and artificial intelligence to enable smart personalized healthcare using PDTs. Several use cases are described, including the mitigation of COVID-19 contagion, follow-up care for COVID-19 survivors, personalized COVID-19 medicine, personalized osteoporosis prevention, personalized cancer survivor follow-up care, and personalized nutrition. Finally, the challenges that need to be addressed to move the PDT paradigm towards the smart personalized healthcare industry are identified [31].

Digital twins, virtual representations that are essentially a real-time digital version of a physical object or process, were first developed by NASA in 2010 to improve the simulation of spacecraft physical models. With the growth of the Internet of Things (IoT), digital twins have become more cost-effective and have been successfully used in the manufacturing and service sectors to transform these industries. Given the benefits that digital twins have brought to these sectors, it is not surprising that they could potentially be used to bring similar benefits to the healthcare industry. This chapter discusses how and why digital twins could be conceptualized for healthcare [32].

Digital Twin (DT) is a technology that creates a digital replica of any physical phenomenon in a digital space, in sync with the physical state. However, creating a Healthcare DT model for patient care is seen as a challenging task due to the lack of a structured data collection system. There are also security and privacy concerns, as healthcare data is sensitive and can be misused. Given these research gaps, it is important to find a way to properly acquire structured data and manage it securely. In this article, the authors present a mathematical data model to collect patient-relevant data in a structured and predefined way with clear boundaries. They also describe the data model in the context of real-life scenarios. Then, they use the patient-centric mathematical data model to formally define the semantics and scope of our proposed Healthcare Digital Twin (HDT) system based on blockchain technology. They describe the proposed system with all of its key components, as well as the detailed protocol flows and an analysis of its various aspects. Finally, they provide a feasibility analysis of the proposed model and compare it with other relevant research works [33].

Ferdousi et al. provide an overview of well-being digital twins (WDT) in the healthcare industry, discussing their potential scope, architecture, and impact. They also discuss the definition and benefits of WDT, the evolution of digital twin frameworks, and the challenges, types, drawbacks, and potential application areas of WDT. Finally, the authors present the requirements for a WDT framework as identified in the literature [34].

This study aims to examine the potential and challenges of using digital twins, virtual representations of physical entities, to manage and predict outbreaks of Covid-19. By providing a detailed model of each patient, digital twins can be used to determine the most effective method of care for that individual, which can improve patient experience and care delivery and reduce demand on healthcare services. The review analyzed 18 papers that met the inclusion criteria and were published in English on the use of digital twins in healthcare. However, none of the included papers specifically examined the use of digital twins in the context of Covid-19 or infectious disease outbreaks. The review identified a need for more research on the use of digital twins in healthcare, particularly in the context of infectious disease outbreaks. The paper presents a preliminary conceptual framework for the use of digital twins in hospital management during the Covid-19 outbreak to address this research gap [35].

Electronic Health Records (EHRs) have collected a large amount of data in recent years, but there is currently no comprehensive approach to using artificial intelligence to understand a patient's overall health. Digital Twin refers to a comprehensive physical and functional representation of an item or system, including all relevant information for all life cycle phases. This paper presents a platform that uses advanced technologies such as Microservice Architecture (MSA), containerization (Docker), orchestration (Kubernetes), and Machine Learning Operations (MLOps) to create a Digital Twin of Patient platform, inspired by Leonardo DaVinci's Vitruvian man. The platform's architecture includes clusters of Docker containers and Kubernetes orchestration to represent specific parts or organs of the body as "digital_twin_components," which come together to form the "patient_digital_twin" cluster. Pipelines are used to define and monitor the construction of the patient's digital twin in real time [36].

Digital twins, originally defined as virtual representations of physical assets, systems, or processes, have the potential to improve medical decision-making through the acquisition, management, analysis, prediction, and interpretation of data. However, there are many challenges and barriers to using digital twins in healthcare. In this paper, the authors propose a dynamic digital twin approach to optimize individual patient healthcare journeys, specifically for women at risk for cardiovascular complications during preconception and pregnancy and throughout the lifespan. They discuss the potential for multiple domains to contribute to the development of this digital twin and outline future goals, trade-offs, and methods for guiding its development and implementation in healthcare [37].

Artificial intelligence (AI) and the Internet of Things (IoT) have improved smart city applications such as smart healthcare, transportation, and environmental management. Digital twins, which are AI-based virtual replicas of real-world entities, have been adopted in manufacturing and industrial sectors but are still in the early stages of use in smart city applications due to concerns about trust and privacy in data sharing. Federated learning (FL), a technology that preserves privacy and trustworthiness, could be used in conjunction with digital twins to improve adoption in real-time and life-critical scenarios and facilitate governance in smart city applications. This paper presents a survey of the various smart city applications of FL models in digital twins, identifies challenges and future directions for improving FL-digital twin integration in future applications [38].

Designing, constructing, and operating healthcare facilities is a complex process in the architectural/engineering/construction (AEC) industry. Creating a systematic and transparent digital twin (DT) architecture with practical use cases would be an important first step in effectively managing these facilities. This study presents a DT system architecture specifically designed for healthcare facility management, with five layers: data acquisition, transmission, integrated middle platform, service, and target. The authors demonstrate how this architecture was used to develop a DT-based smart ward in a Shanghai hospital, which integrates heterogeneous data sources to support real-time data analysis and decision-making, improves healthcare service, and helps bridge the gap between humans and healthcare assets and spaces. The paper also outlines future directions and opportunities for DT-based healthcare facility management [39].

Digital twins, virtual representations of physical systems created using technologies such as Cyber-Physical Systems (CPS), the Internet of Things (IoT), Big Data, Edge Computing (EC), Artificial Intelligence (AI), and Machine Learning (ML), have the potential to optimize a wide range of applications in industries such as healthcare and smart cities. However, digital twins are still in the early stages of development. This paper provides an overview of the technologies used to create digital twins in industry and healthcare, including the characteristics of digital twins, communication technologies and tools, reference models, standards, and challenges and open issues. The authors also discuss their own recent work in the field of smart manufacturing and healthcare [40].

A digital twin is a virtual model designed to accurately reflect a physical object or system. In radiology, a digital twin of a radiological device can be used to test its characteristics, make changes to the design or materials, and assess the impact of those changes in a virtual environment. Innovative technologies such as artificial intelligence and -omics sciences may be used to create digital twins for patients that can be continually updated based on real-time health and lifestyle data. This could be used to improve personalized medicine. In addition, the creation of digital twins based on real-world deployments could enable the use of large virtual patient populations for virtual clinical trials and population studies. Digital twins have the potential to transform how diseases are detected and managed, but there are still significant challenges to be addressed in their development. Radiologists can play a role in introducing digital twins into healthcare as this technology evolves [41].

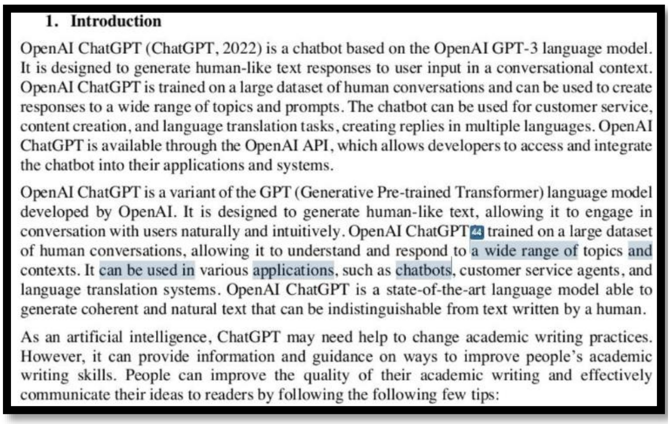
Digital twins, virtual representations of physical assets such as devices, structures, and patients, are being explored and applied in the healthcare industry. While much of the focus has been on creating digital twins as standalone applications, in reality, these assets are often interconnected and part of a larger physical ecosystem. In this article, the authors propose the use of digital twins to create virtual representations of contexts and situations involving multiple related assets within a healthcare organization, resulting in an ecosystem of digital twins. They use trauma management as an example, but suggest that the concept could be applied to virtualize complex physical realities in a variety of contexts [42].

VI. Findings and Results

In the analysis made with the Ithenticate Plagiarism Tool, the similarity rate of the entire article (except the bibliography) was determined as 40%. This ratio occurs when the texts created by the authors and all the texts created by ChatGPT are evaluated. It is better to analyse the overall paper in three different sections:

- Section A: The texts written by the paper's authors
- Section B: The abstract texts of the article paraphrased by ChatGPT
- Section C: The content generated by ChatGPT, which are answers to specific questions

Section A had no noteworthy match, as seen in Figure 1. On the other hand, Section B showed a clear match, as seen in Figure 2. The check of Section C is shown in Figure 3. The matches of these texts are low, but still more than the Section A results.



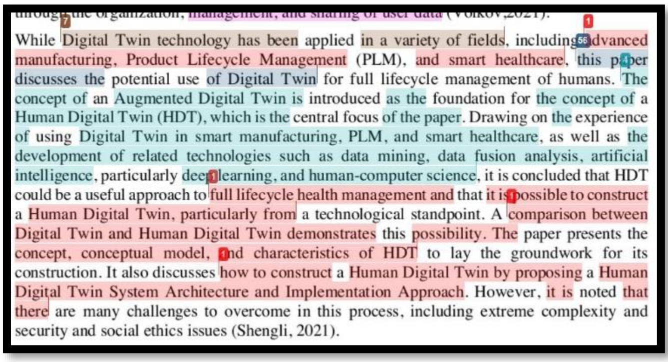
1. **Introduction**

OpenAI ChatGPT (ChatGPT, 2022) is a chatbot based on the OpenAI GPT-3 language model. It is designed to generate human-like text responses to user input in a conversational context. OpenAI ChatGPT is trained on a large dataset of human conversations and can be used to create responses to a wide range of topics and prompts. The chatbot can be used for customer service, content creation, and language translation tasks, creating replies in multiple languages. OpenAI ChatGPT is available through the OpenAI API, which allows developers to access and integrate the chatbot into their applications and systems.

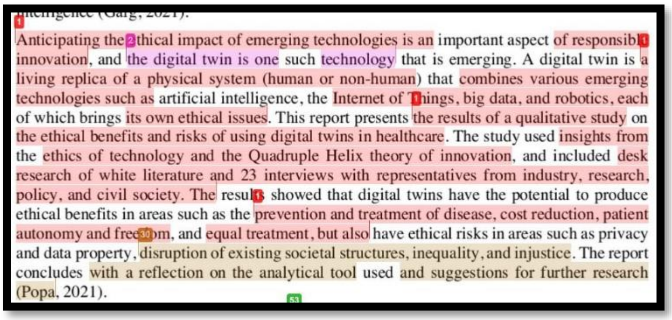
OpenAI ChatGPT is a variant of the GPT (Generative Pre-trained Transformer) language model developed by OpenAI. It is designed to generate human-like text, allowing it to engage in conversation with users naturally and intuitively. OpenAI ChatGPT is trained on a large dataset of human conversations, allowing it to understand and respond to a wide range of topics and contexts. It can be used in various applications, such as chatbots, customer service agents, and language translation systems. OpenAI ChatGPT is a state-of-the-art language model able to generate coherent and natural text that can be indistinguishable from text written by a human.

As an artificial intelligence, ChatGPT may need help to change academic writing practices. However, it can provide information and guidance on ways to improve people's academic writing skills. People can improve the quality of their academic writing and effectively communicate their ideas to readers by following the following few tips:

Figure 1. Plagiarism Tool Match Screenshot for The Authors' writings

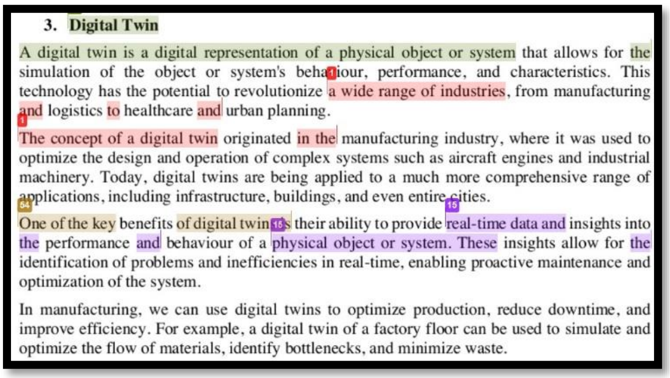


While Digital Twin technology has been applied in a variety of fields, including advanced manufacturing, Product Lifecycle Management (PLM), and smart healthcare, this paper discusses the potential use of Digital Twin for full lifecycle management of humans. The concept of an Augmented Digital Twin is introduced as the foundation for the concept of a Human Digital Twin (HDT), which is the central focus of the paper. Drawing on the experience of using Digital Twin in smart manufacturing, PLM, and smart healthcare, as well as the development of related technologies such as data mining, data fusion analysis, artificial intelligence, particularly deep learning, and human-computer science, it is concluded that HDT could be a useful approach to full lifecycle health management and that it is possible to construct a Human Digital Twin, particularly from a technological standpoint. A comparison between Digital Twin and Human Digital Twin demonstrates this possibility. The paper presents the concept, conceptual model, and characteristics of HDT to lay the groundwork for its construction. It also discusses how to construct a Human Digital Twin by proposing a Human Digital Twin System Architecture and Implementation Approach. However, it is noted that there are many challenges to overcome in this process, including extreme complexity and security and social ethics issues (Shengli, 2021).



Anticipating the ethical impact of emerging technologies is an important aspect of responsible innovation, and the digital twin is one such technology that is emerging. A digital twin is a living replica of a physical system (human or non-human) that combines various emerging technologies such as artificial intelligence, the Internet of Things, big data, and robotics, each of which brings its own ethical issues. This report presents the results of a qualitative study on the ethical benefits and risks of using digital twins in healthcare. The study used insights from the ethics of technology and the Quadruple Helix theory of innovation, and included desk research of white literature and 23 interviews with representatives from industry, research, policy, and civil society. The results showed that digital twins have the potential to produce ethical benefits in areas such as the prevention and treatment of disease, cost reduction, patient autonomy and freedom, and equal treatment, but also have ethical risks in areas such as privacy and data property, disruption of existing societal structures, inequality, and injustice. The report concludes with a reflection on the analytical tool used and suggestions for further research (Popa, 2021).

Figure 2. Plagiarism Tool Match Screenshots for ChatGPT Paraphrased Abstracts



3. **Digital Twin**

A digital twin is a digital representation of a physical object or system that allows for the simulation of the object or system's behaviour, performance, and characteristics. This technology has the potential to revolutionize a wide range of industries, from manufacturing and logistics to healthcare and urban planning.

The concept of a digital twin originated in the manufacturing industry, where it was used to optimize the design and operation of complex systems such as aircraft engines and industrial machinery. Today, digital twins are being applied to a much more comprehensive range of applications, including infrastructure, buildings, and even entire cities.

One of the key benefits of digital twins is their ability to provide real-time data and insights into the performance and behaviour of a physical object or system. These insights allow for the identification of problems and inefficiencies in real-time, enabling proactive maintenance and optimization of the system.

In manufacturing, we can use digital twins to optimize production, reduce downtime, and improve efficiency. For example, a digital twin of a factory floor can be used to simulate and optimize the flow of materials, identify bottlenecks, and minimize waste.

Figure 3. Plagiarism Tool Match Screenshot

VII. Conclusion and Discussion

In this study, we first used ChatGPT to create texts for Digital Twin and Digital Twin in Healthcare titles. The literature review part of the article is created with these texts. The articles published from 2020 to 2022 were selected by searching Google Scholar with the keyword "Digital Twin in Healthcare". Then the abstracts of these studies were paraphrased with ChatGPT. Later on, we asked ChatGPT questions.

In light of the findings and results, the plagiarism tool matching rates of the texts written by the study authors were very low. On the other hand, it was seen that the answers given by ChatGPT for the questions asked were relatively low. On the contrary, the match rates of the abstract paraphrase tests created by ChatGPT are very high. From this information, it can be concluded that ChatGPT does not produce original texts after paraphrasing.

This article is a beautiful and striking example of Artificial Intelligence to demonstrate the point it has reached. It seems possible for the academic literature to reach a different point with this and similar applications. The compilation and expression of knowledge will be accelerated with the help of artificial intelligence, and these processes will require less human-driven procedures.

In future work, citations to our study will be monitored. A new study will be put forward to evaluate the academic validity after we reach a high number (ex. 100) of citations to this study from journal articles. These citations will be grouped as positive, negative, or neutral. Then the evaluations of the article's adequacy will be considered. In this way, we will understand whether the academic community accepts the study we put forward. The contribution of this ChatGPT implementation to the academic literature will be analysed then.

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