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Digital Twin in Health Care

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Abstract: Digital twin (DT) technology has been used in an industry as a simulator for accurate future decisions. Decision-making and prediction play a significant part in the healthcare or medical business as they support resource allocations and the design of new medical practises and approaches. The combination of three systems—the physical, the virtual, and the connecting link layer—is known as digital twin technology. It serves as a copy and offers a real-time virtual representation of actual physical items. The potential of digital twins in the medical field is exciting. A digital duplicate that enables modelling the condition of a real object or system is called a "digital twin". In the healthcare industry, significant advances have been achieved to create digital twins of both patients and medical equipment. By translating the patient's bodily traits and physical changes to the digital world, the patient's Digital Twin is generated. This study emphasizes approved studies that will serve as an outline for future research because of the Digital Twin technology's great potential in the field of health.

Key words: Digital Twin, Health Care , Digital Transformation, Hospitals, Organs, Applications.

1. Introduction

The definition of DT was given as "a living model of a physical entity or a system, which can constantly adapt to changes and predict the future of the corresponding physical response based on collected online data and information.[1]" The term "Digital Twin" was initially used in 1991 in David Gelernter's book "Mirror Worlds," and afterwards used in manufacturing by Michael Grieves. By 2002, Grieves had transferred to the University of Michigan, and in Troy, Michigan, at the Society of Manufacturing Engineers meeting, he officially introduced the idea of the Digital Twin. Data is effortlessly exchanged between the physical and virtual worlds via this connection, allowing the virtual and physical worlds to coexist in real time[2]. NASA's Apollo programme uses the DT technology idea to duplicate two spacecraft for a mission. As one spacecraft is being launched, a second one mimics the space ground model to show the state of a vehicle.

In the field of health, it relates to ideas like detecting and diagnosing diseases before they appear by looking at organs in the body or symptoms. Organ transplantations, replacing the eye lens of cataract patients with a new lens, and conducting a vascular bypass surgery to restore blood flow are all considered engineering activities in the context of atherosclerosis in the health profession.Medical device errors, inaccurate medical findings detection, and misunderstanding of the results can result in erroneous diagnoses, improper treatments, and potentially harmful outcomes. It is crucial to anticipate and prevent mistakes because of this. Misdiagnosis and therapy might cause the patient's critical functions to decline, which could have fatal results or at least irreparable effects on his life. For instance, if the leg muscle infarction is not identified and treated at the appropriate time, or if it is incorrectly identified and treated, it may result in lifelong impairment or loss of the limb. The use of digital twin technology will aid in the rapid and precise detection of cancer disorders. Cancer therapies are very challenging and dangerous procedures for patients, patient family, and medical professionals. We are also able to detect the Type of cancer using Digital Twin. Clinical digital twin activities fall into four categories: Digital patients, pharmaceutical companies ,Healthcare facilities and smart wearable. By using cutting-edge technology like AI to analyse vast amounts of data, Digital Twin make it possible to visualise the virtual twin of the patient[1]. Before physical interventions such as drug therapy, radiotherapy, or surgical operations are performed on the human body, various studies can be done to make sure this is indeed the case
necessarily. Although not preferred in case of difficulties in diagnosing diseases, the method that can be used is to use reconnaissance operation. With the creation of a holistic digital The twin of the human body, disease can be diagnosed examination of the necessary areas on the patient's digital twin ,without using the method of exploratory surgery that can sometimes they are painful for the patient and prolong its duration healing process. If the method of treatment is considered appropriate the disease is tested on the patient's digital twin and is
is expected to produce successful results with a high probability, appropriate treatment can be administered to the patient. Through the use of computer models, digital twins are used to create digital representations of healthcare data, including hospital surroundings, lab findings, human physiology, etc.

The last few decades have supported rapidly growing and mature technologies accelerated a number of business processes and the development of innovative solutions. In particular, it pushed the development of sensor technologies and wireless networks conveyed Internet of Things (IoT) applications and contributed to practical applications application of digital twin technology. (IoT refers to sensors connected to the Internet and devices built into everyday objects or attached to the human body, e.g. which can collect, send and receive data about and/or instrumented entities environment.) Thanks to the Internet of Things, digital twins can now be created that collect much more real-world and real-time data from a wide variety of sources and thus can create and maintain more complex simulation of physical entities, their functionality and changes undergo over time.

In Health Care ,The digital patient twin is being studied and developed in the field of healthcare for certain organs like the heart and liver. There are four prerequisites that must be met for a digital patient twin to be implemented practically: (1)The healthcare facilities, such as hospitals, must be suitably digitally networked. (2)The information has to be organised and annotated.(3)At all times, patients must have the choice of how their data will be used. (4)The data generated in the digital patient twin must be accessible to medical practitioners, and they must be able to use this digital interface in routine clinical practise[5]. Additionally, the Digital Twin will be widely utilised to address the issues with the administration of hospital systems and medical resources that have been with the COVID-19 epidemic, more noticeable. Similar to how COVID-19 will speed up the procedures for developing vaccines and medications, Digital Twin solutions are anticipated[2]. The US Army and the University of Nevada are working together to construct virtual twins of soldiers as another health-related project. Through the use of several imaging methods, including MRI, digital twins of troops will be developed. As a result, it has been suggested that in the event of an accident, organs may be created using the 3D printing technique utilising models from Digital Twins[2]. one of the main advantages of a digital twin in the medical field lies in the possibility of optimizing the treatment given. Our own organ can be modeled in a simulation that reproduces its functioning and its interaction with other elements that are themselves modeled. This is the main reason for the emergence of technology that many systems and organisms can be complex and unpredictable due to the use of many elements injected into them during Digital transformation era and hence management of such complex infrastructure Not an easy task for humans. This problem will be more challenging healthcare systems. For example, consider a patient who has a complex illness such as migraine. A patient can use a pulse maker in his heart, smart glasses to manage his eye disease, and some prostheses in his brain.

A digital twin (DT) consists of the following four parts: A real world, a virtual world, a link connecting real and virtual worlds, a link connecting virtual and real worlds, etc.The advancement of big data, cloud computing, virtual reality, Augmented Reality (AR) and the internet of things (IoT) technologies has laid the technical preliminary work for the use of digital twins (DT), giving doctors and scientists a more in-depth perspective with which to examine the onset and progression of diseases and carry out more accurate diagnoses and treatments. IoT sensors and other data are utilised by DT to assemble real-time data for accurate modelling of resources, which is then combined with AI driven analytics tools in a digital setting. Researchers employ three-dimensional (3D) reconstruction technology to create an intuitive 3D form of the human body, enabling visualisation of the body structure, by digitally processing two-dimensional (2D) cross-sectional pictures of the human body[3].Types of digital Twins are Part Twin, Product Twin, Process Twin and System Twin. DT and its supporting technologies – AI, Cloud computing, DL, Big Data analytics, ML, and IoT[4].Tools of Digital Twins are Microsoft Azure Digital Twin, IBM Watson IOT Platform, Anasys Twin Builder ,AWS IOT TwinMaker And Siemens . The number of articles, procedures, concepts, and expected benefits connected to the Digital Twin has grown significantly during the past five years in both academia and industry. Digital twin is one of the top 10 strategic themes for 2019 according to Gartner. Additionally, according to Gartner, by 2021, 50% of all significant industrial groups will be utilising digital twins, allowing them to boost their effectiveness by 10%[8]. By creating digital simulation models that are updated as their counterparts in the physical world go through changes, Digital Twin is used as a development environment that integrates and enables the running of digital processing algorithms borrowed from Artificial Intelligence techniques (e.g., Machine Learning) and Exploratory Data Analysis (e.g., Software Analytics)[9]. "Doctors are very interested in this type of biomedical engineering tool," Martin Genet continues[16].

2.Literature Review

The following phases are used by Y. Liu et al. (2019) [6] to describe how DTs work in the medical field. First, DT models need to be created utilising cutting-edge modelling methods and software (such as SysML, Modelica, SolidWorks, 3DMAX, and AutoCAD). Second, IoT for health and mobile internet technologies should be used for real-time data connection and sharing between physical and virtual things. Third, fast execution and calibration allow simulation models to be evaluated and verified. Fourth, models are continually modified to improve and iterate DT models. Finally, model outputs (such as diagnosis findings) are returned to the patients in accordance with the virtual twin's behaviour. Regarding the DT application on patients, the ultimate goal is to have a lifetime, personalised patient model that is updated with each measurement, scan, or exam and includes behavioural and genetic information.

In The Digital Twin Revolution in Healthcare[2] They discussed the significant Digital Twin studies carried out in various branches of health, which could lead to new studies, and talked about there expectations about what kind of developments these technologies may undergo in the future. In the future, in addition to the health field mentioned in there study, detailed studies can be carried out on Digital Twin technology from various perspectives such as aerospace, military, education, and safety systems.

In USING DIGITAL TWINS IN HEALTH CARE[9] They focused the benefits offered by DT in processing large volumes of data extracted from enormous medical databases and to highlight the interactions between the constituent elements of these networks. They discussed how they used DT for graph representation of spatial networks, used as models for various types of biological networks (molecular networks, genetic networks), and used DT for graph representation of spatial networks.

Voell et al. (2018)[12] state that the following characteristics characterise digital twins:(a)Comprehensiveness: Digital Twins need to be able to manage data of various forms and combine data from many sources. Digital twins can incorporate a variety of actual item characteristics, from a rudimentary depiction of the thing to a highly complex one.(2)Linkage: Digital Twins are linked to a variety of real things, but they may also be linked to other Digital Twins to form a larger system of linked representations of systems.(3)Interoperability: Digital Twins need to be adaptable and enable communication between parts made by a variety of different vendors.(4) Instantiation: Distinguishing between conceptual and fully operational Digital Twins. While instantiated Digital Twins have functionality gained from live data rather than being shared with other Twins, non-instantiated Digital Twins only have the methods and features they all share.(5) Evolution and Traceability: Digital Twins must maintain track of their evolution since they change just like real items do. Digital Twins maintain track of changes made once knowledge is acquired, whether it comes from the installation of new components or via sensed data, enabling an understanding of how the system or physical thing grew into its current condition.

In A Framework for the generation of digital twins[14] of cardiac electrophysiology from clinical 12-leads ECGs They study serves as a proof-of-concept for the creation of a unique approach for the highly automated creation of high fidelity Cardiac digital twins that mimic ventricular EP. As a measure for model parameterization and comparison of model and data similarity, non-invasive 12-lead clinical standard ECGs that offer a broad yet sensitive picture of total ventricular EP are employed. The workflow takes into account both the functional and anatomical aspects of making a CDT. Our ECG-based functional twinning methodology is built around three major innovations that are essential for producing virtual CDT cohorts at scale, which has previously been difficult or impossible to do. The addition of a reference frame X to the anatomical model, on the other hand, enables unattended manipulation of all parameters in our parameter vector, allowing for sweeps of the entire parameter space, including significant space-dependent parameters relating to the HPS, conduction, and repolarization properties. Last but not least, the parameter vector used in the forward ECG model is extensive and adaptable enough to allow for the inclusion of the most important governing factors for ventricular activation and repolarization to theoretically replicate the greater variability of ECG morphologies in the general population.

Siemens Healthineers[15] Company Mention on There website How they Apply a Digital Twin On a Patient Heart and using Wearable Devices they Detect Cardiovascular Disease. The patient twin continuously measures and gathers vital cardiovascular data, such blood pressure, and integrates it with additional relevant details, including laboratory or imaging-related data. A suitable comparison group of other people's health data is continually compared to the patient's data using artificial intelligence.

Martin Genet Discussed[16] a Customise a Generic model by adding the specific data of an individual organ. Even the interaction of a medication molecule with a sub-network of a DNA molecule may be shown using digital twins of biological tissue.

Abdulmotaleb El Saddik[20] state that the condition known as migraine is complicated. Since the risk factors for this disease have increased due to the digital revolution period, it has become significantly more complicated. In the literature, several solutions based on technologies like AI and IoT have been published. In this chapter, a survey of various solutions was provided. They outlined the shortcomings of the current techniques and recommended potential DT-based fixes.

Additionally, DTs promote cutting-edge treatments for conventional treatments that have not yet been documented in the literature. To assist the beginning steps about using DTs in migraine disease, a number of concerns including development barriers, open research, and managerial implications were also addressed in the discussion segment. This work creates an opportunity in this sector because there is no literature on the use of DTs for treating migraines.

According to Bruynseels et al. [21], there are many parallels between current engineering methods driven by digital twins and data-driven healthcare practises. They pointed out that the latter uses digital twins for complicated system maintenance and predictive management, including identifying broken components and modelling intervention results. In silico clinical analyses aim to achieve this by utilising the dynamic representation of an individual's unique details, such as molecular status, physiological status, and lifestyle, over time in the digital domain. This approach is similar to the idea of using the virtual model to evaluate the impact of actions on the physical model.

Lehruch et al. [22] proposed a personalized care and disease prevention system Through the use of 'virtual twins' or 'guardian angels' for Europe, which is intended Using data collected on a model of the biology of European patients and their disease state. A wide range of domains that characterize the included individuals (eg, clinical, imaging, and sensor data). Computing resources and big data technologies are becoming more

Cost-effective, they envisioned making such personalization increasingly easy Digital models on which clinicians can test all possible treatments and interventions beforehand Prescribing them to actual patients. The value of such an effort would be significantly improved Quality of life for European citizens, while reducing costs associated with care provision.

Cho et al.'s [28] comprehensive analysis of Korean adult females' facial profiles utilising face scans and three-dimensional (3D) imaging (cone-beam computed tomography, CBCT) revealed the efficacy of digital twins in giving suitable orthodontic therapy. The authors created a 3D digital twin of each patient under study by fusing their facial scan and CBCT image in order to account for the differences in facial structures between Korean and Caucasian patients. This allowed them to provide more precise measurements and assessments of the'sagittal relationship' between the maxillary central incisors and the forehead.

Figure 1 shows a steady increase in the number of HDT publications. The growth of the number of HTD-related publications began recently, after 2018. Before 2020, the development of HDT in the academic field is relatively slow. From 2020 to 2022, the number of HDT publications in the academic field increased rapidly.
It shows that HDT is gradually coming out of the embryonic stage and entering the rapid development stage. Researchers have shifted from exploring the concept of HDT to exploring the generic framework of HDT and the practical application and related technologies.

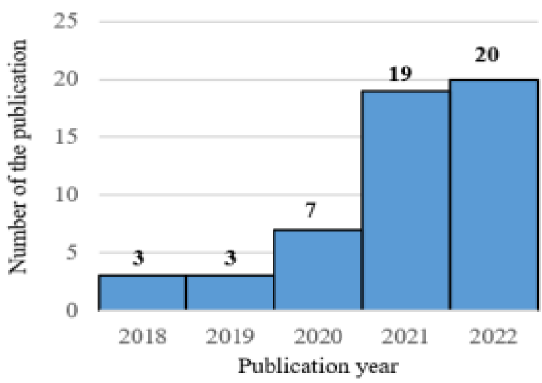

Figure 1: The paper's year of publication in the literature review

3.HealthCare Applications

3.1 Brain

Chinese researchers released a paper in 2018 to better understand how neural networks and memory are connected and to build a three-dimensional brain map of the human brain. To understand more about the research issues raised in the essay, they carried out several investigations in the fields of neuroscience and artificial intelligence. In America, two initiatives called Human Brain Project and Brain Initiative were launched at the same time to analyse the connections and structure of the human brain and transfer them to a computer. One of the divisions of the Human Brain Project is the Blue Brain Project[10]. High-risk migraine attacks might be identified using DT-based techniques. It may be possible to stop dangerous migraine attacks using this skill[20]. The French start-up "Sim&Cure" has made strides in helping doctors restore brain injuries while creating a virtual patient to cure aneurysms[35].

The **Blue Brain Project** at Hewlett Packard Enterprise collaborated with Ecole Polytechnique Fédérale de Lausannes (EPFL) is a Swiss brain research initiative run by Professor Henry Markram, its founder and director and The main objective of the Digital Twin of Brain is to link a human brain with an artificial brain. High-level computational methods and supercomputers with lots of storage capacity will be used in order to create artificial brains that can mimic the functioning of human brains and download crucial data about a person, including their knowledge, emotions, and memories. Every individual has a finite amount of time on this planet. All of a person's wisdom and knowledge are lost to them when they pass away. However, before a person passes away, all of the data in their brain is permanently maintained using an artificial brain. In order to learn how to cure conditions like Parkinson's and Alzheimer's, we may also employ the artificial brain. The brain communicates with supercomputers using tiny robots dubbed "nanobots." For the spine and brain nerves, they are too tiny to enter. The nanobots then begin scanning the brain and observing the architecture of the neurons after they have entered. The sole method for linking two computers is by nanobots. The programme is known as "BBP-SDK," a software development kit including Java and Python wrappers and C++ code. The BBP-SDK gathers data from nanobots, and "RT Neuron," a C++ data visualisation programme for 3D neuron simulation visualisation, is used to demonstrate what that data represents. The final information will be utilised to create more models of how the brain functions and saved in databases. If this experiment is successful, it will be feasible to save and review data on the brain According to Blue Brain Project.[11]

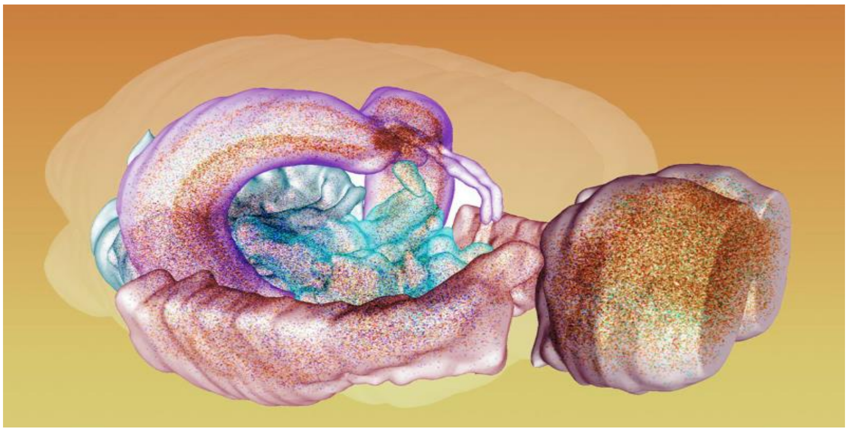

Figure 2: A digital example of a brain image from the Blue Brain Project [10]

3.2 Heart

The advantages of converting nonclinical data into a digital twin format to notify medical personnel when action is required are the first of many prospects for digital twins in cardiology[19].A cardiac research study named Echos, directed by Frank Rademakers of University Hospitals Leuven in Belgium, is where the concept of producing digital heart twins originated. A recent effort called EurValve, directed by Rod Hose, a former aerospace engineer who is now a leading authority on medical modelling at the University of Sheffield, established a method to aid physicians in treating patients with heart-valve problems. Health-tracking watches made by the Dutch technology company Philips were used by EurValve to integrate data collected from scans and other hospital testing with information gained from patients while they were at home. The EurValve technology, which the researchers believe will soon be implemented in clinical practise, can simulate the degree of illness and forecast how heart valve replacement operation will turn out.[13] A digital twin of the whole heart will enable the simulation of the treatment of a specific individual for many other conditions. doctors will benefit from a new depth of knowledge about how their patients' hearts are working. Cardiac digital twins of human electrophysiology are digital representations of patient hearts created from clinical data that match all available clinical findings like for like.

Though they have made progress, digital twins are still not advanced enough to fully analyse the human body. As an illustration, the software company "Dassault" recently unveiled "Living Heart," the first accurate virtual representation of a human organ that takes into consideration blood flow, mechanics, and electricity. A 2D scan of a person may be converted by the programme into a precise, three-dimensional representation of that person's heart. The model was developed in collaboration with educators, cardiovascular researchers, medical device developers, doctors, and several institutions. Doctors were able to use computer simulation to analyse the complex structure of the heart by playing with the same organ model and seeing what they are unable to view owing to the flexible nature of the heart tissue. By entering the patient's unique vital signs, it facilitates personalised therapy and offers hope for future medical study.[32][33]

Developed by Philips, the "HeartModel" An essential step towards the concept of the digital patient is the creation of a personalised Digital Twin of the heart. HeartModel transforms the generic model into a personalised model based on the distinctive heart photos. The Philips HeartNavigator tool, which was also created by Philips, fuses the Computed Tomography (CT) pictures collected before to the surgical process into a single image of a patient's heart anatomy with a layer of live X-ray data during the procedure. The tool makes before procedure planning simpler, assisting the surgeon in choosing the best equipment. allows for the positioning of the gadget during surgery using real-time 3D insight. This gadget is a physical guide for the surgeon on how to proceed[17].

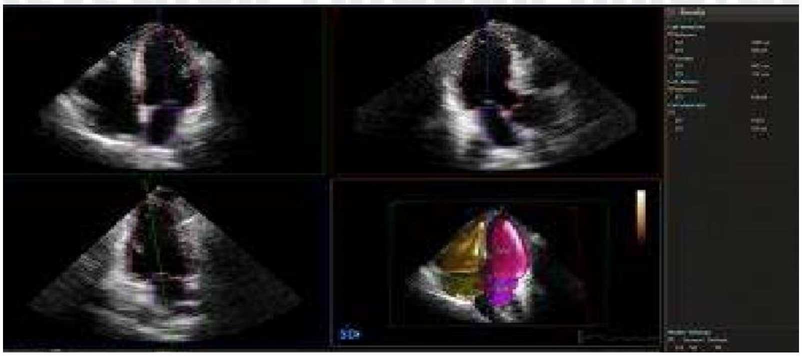

Figure 3: An Example Heart Image from Philips HeartModel[18]

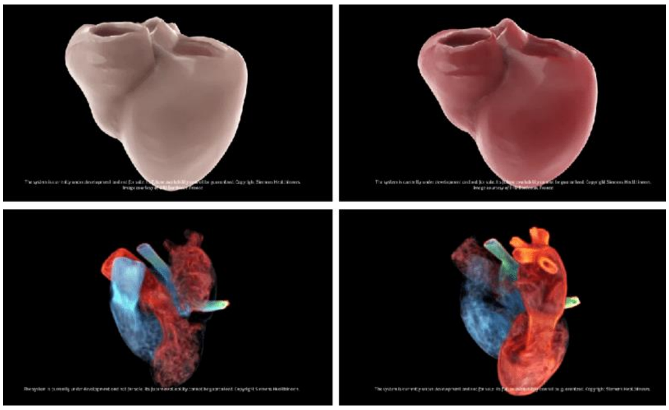

Figure 4: 3 -Siemens Digital Twin visualization of the human heart.

3.3 Lungs

In March 2020, sophisticated computational fluid dynamics (CFD) solver firm LEXMA and cloud simulation business OnScale launched Project **BreathEasy**. Early proofs-of-concept (POCs) for Digital Twins of Human Lungs were created by the two businesses utilising genuine, anonymised COVID-19 patient data from CT and X-Ray imaging. As far as the study of Martin Genet and the MDISIM team is concerned, the disease in discussion is pulmonary fibrosis, a condition that is intimately linked to tissue mechanics, particularly an excess of collagen in lung tissue. Too much collagen makes the tissue hard because it is rigid. A person with too much collagen will eventually force his or her breathing, which will worsen the illness. Martin Genet says, "This is the core feature of our research. To determine whether this recurrent concept is true and whether mechanical restrictions tend to encourage the development and/or evolution of the disease"[16].

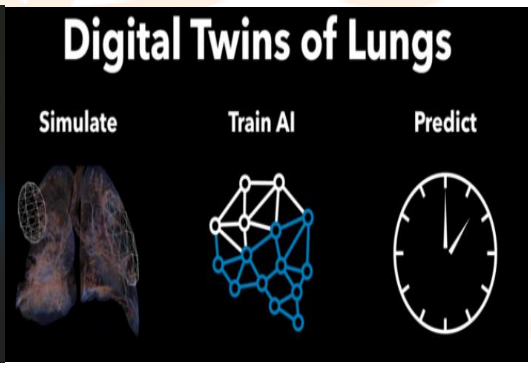

Figure 6: Digital Twin of Lungs Figure 7: Optimize Ventilator Resources

3.4 Liver

The development of a digital twin of the liver by integrating the knowledge and understanding gained by studying various liver functions, diseases and the effect of drugs, using a mathematical framework based on ordinary differential equations.

A digital twin of the liver is being created by researcher Chloé Audigier. They use Large Amount of data to build a general model that represent the anatomy so the liver shape, vasculature and also the lesion circulation inside the liver as well as hepatic function .they develop model that could represent blood flow More people are being affected by liver problems including tumours or fatty liver disease. With just a 16% mortality rate, liver cancer is the third worst kind of cancer globally. However, there are many phases of liver disease, and individuals may receive treatment if they received a timely diagnosis. Therefore, both early diagnosis and better treatment options are required. In the case of liver cancer, for example, an option is to remove the cancerous cells through surgery. The surgeons could use a digital twin to virtually perform the operation and assess the patient's remaining liver function, which is a crucial to understanding whether it's safe to perform the surgery on the patient.[25]

3.5 Physiotherapy

The Digital Twin technology may be applied in the area of physiotherapy to track patient muscle growth, spine cell changes, and bone movement during physical treatment for disorders like scoliosis. With the use of the patient's personal information, predictions about the outcome of the therapy may be produced. Information regarding the type of treatment that may be used was made possible with the production of digital twins of these patients who undergo physiotherapy as a consequence of in-vehicle and out-of-vehicle traffic accidents or paralysed patients to enable them to stand, walk, and return to their previous lifestyles. Additionally, a variety of Digital Twin studies on changes in exercise and muscle activity may be carried out to determine whether strain or workouts have the intended impact, due to real-time data sharing. By observing the patients' conditions and if the therapy has the desired impact, it is possible to determine how the patients react to the treatment. Additionally, time is saved and expensive therapies that will not benefit the patient are avoided by comparing several treatment options on the patient's Digital Twin to see which one is best.

Development of products using muscle activation Technology and electromyography (EMG) for new. Dimensions in understanding muscle behaviour, Myontec Analyses muscle activity and their responses Exercises according to the general health of the body and Thanks transfer them to the digital environment Technology is placed between the threads, and makes more Effective exercises in light of this data. the company Examines the user's activities through the shorts they have developed, calculates the threshold at which muscles Performs optimally, enhances training efficiency and provides Information on reduced warming and cooling times risk of muscle injury [23]. Integrated technology in A product called Myontec Mbody Pro measures electrical Provides muscle activity and during training An understanding of how they behave in what situations.
With sensor technology in the product, it records and Analyses EMG data in muscles including the heart Rate, heart rhythm and heart rate. Thanks to real-time data and Post-exercise analysis, it allows users to do their work Techniques are healthy and efficient, and to detect and prevent
Problems like imbalances and deviations in your muscles system [24].

Figure 8: Digital twin of human body[31]

3.6 Cancer

A patient's tumour or the full cancer system may be represented virtually by a "digital twin" in the context of cancer. It incorporates several kinds of data, including genetic data, clinical data, imaging scan results, and treatment history, to produce a through model that closely resembles the behaviour and traits of the real cancer.

Women aged 50 and over are regularly called in for a mammogram – an X-ray of the breast – with the aim of detecting breast cancer at an early stage. Depending on individual circumstances, this screening might be too early, too late, or not necessary at all. “A digital twin allows us to make a better assessment of the situation,” says Professor Michael Uder, deputy medical director of Universitätsklinikum Erlangen. It also provides physicians with a new tool that allows them to tailor treatment precisely to the individual patient, says Uder.[5]One key advocate of the development of a digital twin for breast cancer screening is d.hip, an alliance made up of Siemens Healthineers, Friedrich-Alexander-Universität Erlangen-Nürnberg, Universitätsklinikum Erlangen, and Medical Valley. The aim is to give women the option of being accompanied by “digital sisters” in as little as around five years.

IBM, together with the supercomputer Watson, has a goal simulate biochemical processes in the body using artificial ones intelligence techniques to detect cancer cells in health data acquired from the past. However, the interaction 37 trillion cells that make up the human body is a process that is hard to understand and almost impossible to follow. However, although each cell has different characteristics carries the same genetic information. Caused cell damage it can cause cells to divide and multiply for various reasons
uncontrollably and the formation of tumors. Alacris computer the model can interpret evolving situations by understanding why a cell divides and the variables that cause it to do so its death by 800 genes and 45 biochemical methods. Thus, which drugs can stop the proliferation of dangerous cells uncontrollably can be tested on digital twins of patients.

In the group of patients with cancer, mucosal tumor in the frontal sinus could not be killed as a result chemotherapy, immunotherapy and radiation received during normal healing processes. However, 70% of the cells division uncontrollably, as a result of submission a drug developed only for breast and kidney cancer that was designed in Digital Twin, data obtained from tumor biopsies after several months show that the speed of dividing cells decreased to 15% [27].

The National Cancer Institute (NCI) and the U.S. Department of Energy (DOE) have formed a strategic interagency collaboration, with Frederick National Laboratory (FNL) serving as a lead organisation. FNL has played a key role in the development of novel technologies for building a digital twin of a cancer patient. Future applications for a cancer patient's digital twin include personalised medicine, cancer research, preclinical development, clinical trials, diagnostics, and therapy simulations. The integration of these skills remains a significant issue for the convergence of advanced computing technologies and oncology, even if some aspects of cancer patient digital twins are already being researched. A patient's digital twin would be the best source of information for individualised care. The information might help doctors choose the best course of action and assist patients in balancing their treatment options with their own preferences and limitations. This technology may be an effective tool for enhancing doctor-patient communication and promoting informed patient choice and team decision-making.[26]

The Harvard Medical School, the Broad Institute of MIT and Harvard, the Dana-Farber Cancer Institute, and other organisations are working together on Project DRIVE (Digital Reasoning for Cancer Evolution). To analyse tumour growth and treatment response, the research will make digital twins of specific cancer patients. It focuses on combining clinical, imaging, and genetic data to create prediction models and enhance therapy selection. For patients with colorectal cancer, breast cancer, and prostate cancer, personalised prediction models will be developed as part of the Digital Twin for prediction Oncology project, which is run by EIT Health. To create digital twins that can model tumour growth, predict treatment response, and aid clinical decision-making, several European organisations, including academic institutions, hospitals, and commercial partners, are working together.

Digital twins are a current focus of the UK-based The Institute of Cancer Research efforts in cancer research. To forecast tumour behaviour, uncover therapeutic vulnerabilities, and optimise therapy for specific patients, they use computer models and simulation tools. To improve the subject of digital twins in cancer, the ICR works in partnership with other scientific organisations and business partners.

3.7 Type 2 Diabetes

Replicas of patients, often known as digital twin technology, is a relatively recent idea in medicine. A digital twin can assist anticipate a patient's reaction to a new medicine or show what lifestyle modifications will best manage, reverse, or avoid chronic illnesses using data ranging from age and weight to exercise levels and smoking status. The Whole Body Digital Twin was created as a tool that can be used on an app to show a person's metabolism. The software enables medical professionals to suggest numerous modifications to diabetes patients by combining blood tests, biometric data, and information from the patient. Type 2 diabetes appears to be under control, and maybe even reversible, at this level of accuracy.

The Whole Body Digital Twin system, which consists of five wearable sensors, gathers 3,000 data points on each individual who has a digital twin every day. Data is gathered by using:1)a sleep and step tracker on an activity monitor. 2)a constant blood sugar metre. 3)an air pressure gauge. 4)a scale that assesses both body weight and body fat. 5)Ketone metres. Patients enter data and respond to questions about their food, way of life, and level of exercise using an app using the data that has been supplied to them.[29]

3.8 Drugs

Scientists can change or remodel medications by taking into account particle size and composition properties to increase delivery efficiency thanks to digital twins of pharmaceuticals and chemical substances.[31]

A key use of digital twin technology is drug placement. Repositioning already-approved medications for use in new indications has the potential to be successful, as seen by the history of drug development. By allowing programmes to use the studies conducted to support approval in the main indication, repositioning reduces the time and money required to create new medications while maximising the value of compounds. However, repositioning has always depended on chance because there is no systematic approach to find further clues. Digital twins might make it possible to conduct scaled, methodical searches for repositioning opportunities. DeepLife Digital Cell might speed up repositioning and, in doing so, reduce the time it takes to obtain therapies to people with unmet medical needs by forecasting how a cell would respond to authorised chemicals. Now, DeepLife is demonstrating how its technology can fulfil that promise.[36]

It is hoped that the development of medications would go more quickly and fewer animals will be used as test subjects as a result of the introduction of technology in the area of personalised medicines. Additionally, research is done to identify and minimise medication adverse effects as soon as possible. The active components of several medications can cause allergic responses in some people. When using antibiotics that contain Sulfonamide, for instance, a patient who is allergic to that substance may experience rash-like responses as well as potentially fatal circumstances [37]. Allergic responses to several of these chemicals can result in serious health issues. Many people are allergic to these drugs but are unaware of it. For this reason, before giving patients specific drugs that might trigger an allergic reaction, certain chemical features in the Digital Twins of the patients can be checked. Doctors can administer medicine on the real patient in a controlled way and by looking at real-time data feeding the patient's Digital Twin to detect and avoid any consequences that may emerge early in allergies that cannot be diagnosed by blood testing, such as sulfonamide.

Dassault Systèmes and the US Food and Drug Administration signed the SIMULIA Living Heart project in the first research to employ Digital Twin technology expressly to observe how an organ interacts with medications was signed a five-year deal in 2014. It is hoped that this study will help minimise the use of animals in drug testing.[32]

Based on compiled data and patient histories, Semic Health's Digital Body Total has created the Digital Twin of Artificial Intelligence-based human biological systems, organs, or molecular systems to assist in the diagnosis of existing medical ailments and forecast potential health issues. Testing situations such as changing medication dosages for the treatment of several illnesses such as various cancers, hepatic sclerosis, acute myocardial infarction, and Alzheimer's disease on Digital Body Total can lead to realistic forecasts.[34]

3.9 Devices

A digital twin of a medical device gives designers the ability to test the functions or properties of a device, make changes to the design or the materials, and evaluate the effectiveness of the changes in a virtual setting before manufacture. This greatly improves the performance and safety of the finished product while lowering the expenses associated with failures.

3.10 Digital Twin of Hospitals

Due to the rising patient demand, growing wait times, etc. at the radiology department of Mater Private Hospitals in Ireland, a Digital Twin study was conducted with Siemens Healthineers to enhance hospital procedures. A Digital Twin of the radiology department was constructed as part of the project and was fed actual data. A number of predictions were made using the digital twin, and a number of situations were tested on it.

Data from systems and immediate interactions among people, processes, and linked items are combined in a smart hospital digital twin. It offers a situational model of a hospital's past, present, and maybe even forecasted future states that can be adjusted, examined, and improved as AI/ML develops. To genuinely make a hospital "smart" via awareness, this data may also be made accessible to a variety of interfaces, apps, and systems.

A novel method of modelling, managing, and using hospital data for action is made possible by a smart hospital digital twin. A smart hospital digital twin can provide the following advantages: Improved patient experience improved healthcare results, reduced facility running expenses, increased safety, and reduced energy use. Hospitals may implement a real-time health system by using digital twins to: Analyse the entire situation in real-time, Take prompt action, monitoring and enhancing. Hospital organisational level usage of digital twins is a good illustration of this. Hospital managers, physicians, and nurses may gain significant, up-to-the-minute insights regarding patient processes and health by building a digital twin of the facility. Digital twins offer a better means of analysing operations and informing the appropriate people at the appropriate moment when instant action is required. They use sensors to monitor patients and coordinate equipment and workers. In turn, this can save operating costs and enhance patient satisfaction by reducing emergency room wait times and streamlining patient flow. After deploying digital twin technology to eliminate bottlenecks in patient flow and bed management, one hospital saw a 900% increase in cost savings. More lives can be saved by using digital twins to forecast and prevent patient crises like cardiopulmonary or respiratory arrest, often known as code blue events.

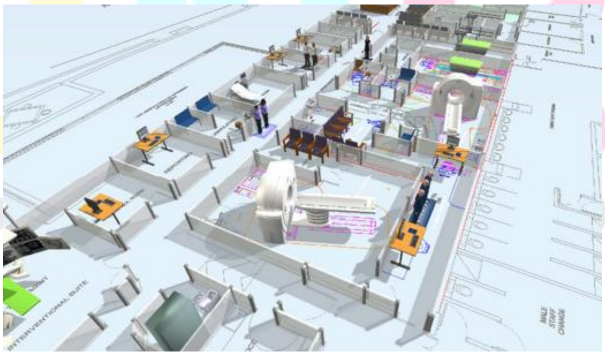

Figure 9: Realistic 3D Animation of Hospital [42]

Conclusion

The production of twins of human bodily organs has been the major focus of digital twin studies in the field of health. In the near future, wearable Digital Twin technologies will be applied to examine changes in the musculoskeletal system of patients with mobility impairments as well as paralysis.

we studied the DT technology and the applications of DT in medicine. We concluded that DT will be more widely used in the medical field to solve the problems, such as real-time monitoring, dynamic analysis and precise treatment for diseases, which cannot be fully explained by traditional methods. It can model the perception and action of any relevant facility in the medical environment, coupling the observable state of the DT with the state of the physical entity (PE). Although, DT technology has technical and ethical problems in the medical field that need to be solved urgently, the progress is encouraging. The use of DT in medicine is not only limited to the diagnosis and treatment of diseases, but can also be used for the prediction of health and disease states, which provide a quantitative understanding of health and disease. DT healthcare, as a key fusion approach of future medicine, will realise precise medicine and bring the advantages of personalised treatment to reality

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