Digital Twins in Medical Field and Patient Data

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***Abstract*—The field of medicine has evolved greatly over the past century. However, medical treatments are still largely inefficient and uneconomical. With the advent of developing technologies like digital twins emerging in industry 4.0, huge leaps are being made in the areas of medical treatment and diagnosis. This paper analyses certain digital twin model concepts and initiatives that have been researched for treatment in various areas in the medical field.**

I. Introduction

What is a digital twin? A DT is a depiction of an existing entity or object. In other words, a replication of its real-world twin; think of it like your shadow but using AI. Digital twins are slowly making its way into the roots of industrial processes and machines, however, has recently been extended to encompass living beings. Tools including sensors and data sources are being analyzed to produce a replication of a human. In hindsight, the aim will be to offer a digital twin in the field of medicine, healthcare, and the well-being of any human whom is need of an event or emergency.

II. Digital Twins: Bridging Physical Space

A digital twin is a virtual shadow of the human body. Like a digital representation that reflects the status and tracks the twins evolution as time progresses. DT's are slowly making their way up to the the mainstream approach to digital transformation. According to Market and Markets, their market value will reach 15.3 billion in 2023. By using digital twins, we are able to create a virtual model of any physical object that may be used to predict, simulate, and analyze throughout the design phase. It will predict, simulate, and analyze behavior, as well as keep track of evolution. Since 2013, GE has used digital twins in its production processes as well as in the monitoring and management of equipment operations. Digital twins are expected to save the corporation 1 billion in annual losses according to the company.

The consensus is that DT applications will proliferate in the majority of domains during the next decade, keeping in mind that the capabilities of DT will improve. The field of health and medicine is a main example of how DT applications are dominating the domain. One of the most promising is found within medical industry. You can see such applications in taking action by General Electric to imitate and monitor hospital operations. However, digital twins will likely be used on people in the next ten years. We can anticipate having digital twins monitor and track the evolution of our health and provide us with therapies as technologists utilize the huge volumes of available data. To assess the efficacy of medications, organs on chips are currently accessible. In terms of operation (harvesting cells and and keeping them alive), they're quite complicated systems, and anything that might make the path to a tailored cure a little easier would be greatly appreciated. [9]

III. Digital Twins and Diseases

A. Using DT's to Simulate Human Hearts

Digital twin technology could revolutionize current cardiovascular disease treatment and prevention. This advancement would help minimize the excess of trial and error involved in treatment. Digital Twins technology simplifies this process by mirroring reality and discovering issues that may remain undetected through conventional methods. This technology represents the next step in providing better comprehensive treatment options for patients. In terms of cardiovascular treatment, the data recieved from a patients DT will allow MD to create treatemnt plants with more specificity and use the digital twin as a testing ground to discover an optimal treatment to prevent or combat cardiovascular disease. [5].

The Living Heart Project (TLHP), is an excellent example of this being put into action. It was founded to create a computer model of the human heart, the first to ever exist in our time. One of its successful patients, by the name of Jesse Levine, was born with a reversed heart, where the right ventricles of the heart were swapped with the left. Her unprecedented condition required her to implant 4 pacemakers to ensure the proper functioning of the heart. The team at THLP created a digital twin that simulates a proper functioning heart. This is a treatment which is used in the case of heart failure. It makes the use of a pacemaker with electrodes connected to the left and right ventricles.

The Living Heart Project aims to create a detailed functional computer model of the human heart. A functional heart model would allow physicians and surgeons to analyze patient health and surgeries, similarly to how products in the auto and aviation industry undergo advanced simulations to detect issues and needed optimizations. The goal of this project is to unify healthcare specialists, regulatory bodies, and medical device companies to work together around aspects of disease models and human anatomy. This project is currently being used to research drug safety and efficacy, developing new medical devices, and creating more personalized treatments. It will be used to improve personalized treatment. In the future, clinical care teams and device and drug development companies will integrate this type of technology into their lineup of treatment options. This would mean personalized treatment plans become more accessible and enable the general public to understand, maintain, and monitor their health with improved effectiveness.

B. *Using DT's to Detect Heart Diseases*

Based on the data from the US Institute of Medicine, around 400,000 people lose their lives due to missed and delayed diagnosis, corrupted health data, or data inefficiency. The Digital Twin (DT) has shown promising results in the health care system. The objective to reach in general is to have fewer errors and better performance in healthcare services. Because even one simple error can play a vital role in a patient's life. Digital twins complete such a process by taking advantage of AI, IoT, Data Analytics and physical objects [1]. As a result, the chances of error decrease.

Ischemic heart disease (IHD) and myocardial infarction, a type of IHD, is a disease that kills millions of people a year. In 2016 the WHO reported a total of 56.9 million deaths and those 56.9 million, 15.2 million were due to IHD and myocardial infarction [14]. These diseases are incredibly difficult to detect early on, and most are not aware they have it until it's too late. Doctors could do continuous monitoring of their patients, but that is nearly impossible and doctors simply cannot monitor patients that often. These patients would have to have daily check-ups for continuous monitoring.

Two researchers were aware of the challenges doctors faced and were aware of the millions of deaths the disease causes. This was their motivation for creating a digital twin of a human heart. For their digital twin, the researchers gathered data from medical records, social networks, body area network sensors, and other external sensors from smart devices (e.g. smartphones). To gather this data the researchers used smartphones due to the technology already included in them, such as GPS, gyroscope, camera, mic, etc. The researchers also found that a smartphone was able to run a machine learning algorithm without a problem.

As for the DT, the researchers created an exact copy of the heart taking into consideration the healthcare and well-being of humans. Again, the researchers used smartphones and ECG sensors to gather the data necessary to create this model. The data was then added to data model, which stores and recovers information. This way the data could be worked on by an AI system. The smartphones made it possible for the researchers to track the information of all the patient's heart information virtually. Their model had an accuracy percentage of 85.77 percent.

This model opens the possibility of doctors and physicians being able to continuously monitor the vitals of their patients without ever having to see them physically. They would be able to detect any abnormalities in their heart condition before it's too late.

C. *Using DT's to Find Optimal Implants*

A French startup named Sim and Cure were first to commercialize a digital model for aneurysm therapy. An aneurysm can lead to a stroke or death and can be found in 2 percent of the population. While brain surgery is an option to repair an aneurysm, it's extremely risky. Sim and Cure simulate a custom design looking at patient's particular anatomy to provide the data needed beofre implementing the model. Finally, Sim and Cure's model uses a tool by the name of "3D rotational angiography" which will simulate a model of vessels, veins, and aneurysm in the vicinity. Sim and Cure's software then sends the created model and presents it to the surgeon where he is importing the artery model and displays it to the surgeon, who then selects the locations that define an appropriate artery location as well as the implant dimensions to be put in place. The clinician can zoom and rotate the photo using ANSYS software which will properly comprehend the link between aneurysm and implant. Another advantage this tool provides is the ability to color label. This can be utilized to illustrate where the implant makes contact with the embolism (occlusion). Any void or empty space is visible in a cross-sectional profile. The simulation may take up to 25 seconds, depending on the hardware Additional devices and sizes can be easily selected and simulated by the surgeon for study to decide which will return the best outcomes.

IV. Using DT's to Improve Health

A. *Digital Twins in Fitness*

A group of human Digital Twins (DTs) is described in our research. The DT tracks down fitness-related measurements which will define the athletes behavior over a specific number of days. This includes the food income, sleep, and his activity throughout the day,. Once the data is gathered, the DT will predict the twins performance whilst he is training and run an if statement. If the results of his training is less than ideal, he will be advised to the change his conduct. SmartFit is a software for assisting coaches and trainers in managing and tracking the athletes fitness activities and outcomes[5].

How does it work? The Fitness Management Digital Twin gathers data commited from the physical twin and reconstructs itself in order to be in tune with it. A study that describes an application for human DTs: SmartFit is a software framework which uses a teams of Digital Twins, linked and programmed to an individual member, to manage and track the physical activity of the team. SmartFit was created to capture a set of metrics defining each athlete's activity over some time, usually a few days. Physical sensors incorporated in world wide devices such as watches, phones, and wrist bands. The devices track the number of steps you have taken, the amount of sleep, your food income, and your physical activity.

Witch the devices storing such data, trainers are able to find and identify any unordinary behaviours your body may commit, hence, preventing or avoiding and serious medical issues. SmartFit intends to provide any user with an environment in which they may create rules using a simple, visual language that they are comfortable with. These rules are used to track occurrences linked to an athlete's habits and are automatically triggered to alert the athlete whose conduct needs to be changed.

V. Medicine and Digital Twins

Despite improvement in previous years, medication can still be ineffective for a large number of patients. According to the FDA (US Food and Drug Administration), up to 75 percent of patients do not react properly to medication diagnosed for common diseases. In the current healthcare system, patients are treated after analyzing only a few biomarkers. This does not take into consideration hundreds of genes that largely vary for different patients. [7]

SDTC (Swedish Digital Twins Consortium) aims to try to find a solution to these issues by taking vast amounts of information from patients through wearable devices, medical records, etc. The aim is to digitally test patients for diagnostics, which is more economical, less time-consuming, and highly effective. It uses the digital twin concept to computationally provide accurate diagnoses for patients with common diseases. This is done in the following steps:

- Developing unlimited digital twin copies of the patient, taking into consideration all environmental and molecular factors which are applicable to a given patient.
- Implement computations of thousands of drugs on these digital twin models, and find out which drug is most effective
- Finally, the patient is treated with the most suitable drug.

However, this approach requires more factors to be considered for accurate diagnostic decision-making. Using molecular factors itself is not enough, we would need to consider additional factors like environment and patient symptoms. This means that the digital twin copies cannot be based purely on molecular profiles. One method to overcome this is to make use of multi-layer modules. Multi-layer modules integrate various network modules which are relevant to a given disease. For example in an asthma patient, modules related to coughing and modules related to wheezing can be integrated. This can result in the construction of disease models with great detail in patients. These models can further be used to develop better testable digital copies/digital twins of a given patient. [7]

VI. Challenges of Digital Twins in Healthcare

Despite growing popularity, the concept of digital twins is still fairly new. There are a few obstacles and challenges that are present that need to be addressed before a DT can be integrated into our day-to-day lives. The first challenge is to ensure that the Digital Twin design replicates the physical body almost identically. The exchange of information from the physical body to the twin should be effortless and comfortable to use for the user. In terms of healthcare, the human body naturally has a lot of factors involved that increase complexity of analysis. These factors include age, height, genes, response to a particular medicine, tolerance, etc. Sensors present in the Digital Twin need to analyze these factors as they vary for every single person. Incorrectly analyzing these factors may result in false-positive results. A few more challenges with the integration of digital twins are listed below [7]

A. Privacy

Information acquired by the digital twin of a patient is confidential and risky. At a time when cyber-attacks are rampant, the proper security of these highly sensitive patient records needs to be ensured to maintain the safety of the individual. This data must only be available to the individual patient and the physicians involved. (DDoS) Denial-of-service is another IoT threat that is present. This can cause entire healthcare systems to shut down furthermore causing danger to the lives of patients. Thus, cyber-security needs to be guaranteed to prevent medical hijacking. [8]

Another important measure is to put in place proper regulation of laws so that the limits of AI and Machine Learning can be defined. This is to ensure the safety of data at all times. The big data accumulated by a patient(s) digital twin generates an enormous amount of information. This makes it very easy for data to be prone to cyber-attacks and certain security frameworks need to be put in place. [7], [8]

B. Ethics

Digital twins being a new technology, it is still unclear as to what is ethically acceptable and what is not. Thus these boundaries need to be decided and written down. The integration of digital twins in society is bound to create a divide among the masses. Patients on the high-end can take advantage of personalized medicine to improve themselves digitally. However, being a much more expensive option than an over-the-shelf alternative, this will not be accessible to a large section of society. If these technologies do not get cheaper, it will result in creating a divide and segmentation of people, with different groups of people having a higher level of accessibility.

Issues regarding the ownership of patient data also need to be addressed, before digital twins can be introduced into the present medical and healthcare system. Guidelines need to be made as to who would be the rightful owners, either patients or the hospitals involved. Questions regarding whether the government or the private sector will have a bigger role in using patient personal data need to be asked and addressed [8].

VII. The Future of Digital Twins

In the long run, medical copies will be tested to predict the chances of being infected by diseases. A persons medical copy will be exposed to various environments to determine which ones enhance or decrease risk. Smoking, for example, will greatly raise the chance of cancer or autoimmune illnesses in a patient at risk. To prevent disease, the twins may be updated and checked regularly. This practice will be recommended to be done across the board and would be accompanied by disease mechanism education.

Medical professionals in the future will be able to diagnose patients for illnesses and recovery plans from surgery by looking at medical twins of a patient. As Dr. Rehman from JH Children's Hospital in Florida claims, digital twins will be used as litmus tests to observe changes in the body. That data can be used in the future to prevent unwanted outcomes in the actual patient.

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