JOUN
TECHNOLOGIES

Digital Twin in Healthcare

Sary Yehia

Abstract

Digital transformation is revolutionizing several industries, enabled by technology advances in computational power, connectivity, and artificial intelligence. Digital transformation has been accompanied by some promising tools, one of which is the digital twin. This paper gives a general overview on the concept of the digital twin with a particular focus on the healthcare sector. It highlights the benefits of the digital twin in healthcare, the contribution in building a smart healthcare system, and the critical privacy and complexity challenges correlated with implementation.

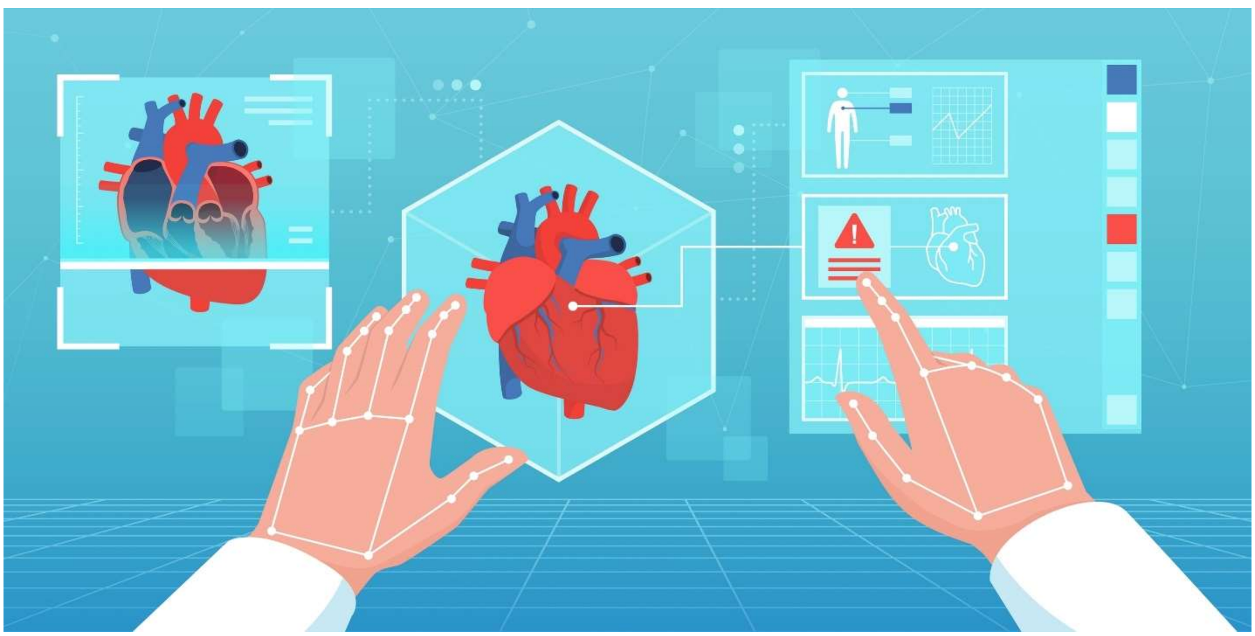


Table of Contents

Introduction

Digital transformation was first defined and introduced in business in 2013. [1] This transformation was not so much a stand-alone industry as it was an approach for introducing technology to a variety of workflows. The health information technology market is expected to hit $390.7 billion by 2024 driven by big data, smart manufacturing, and digital twins. [4]

Current Issues in Healthcare

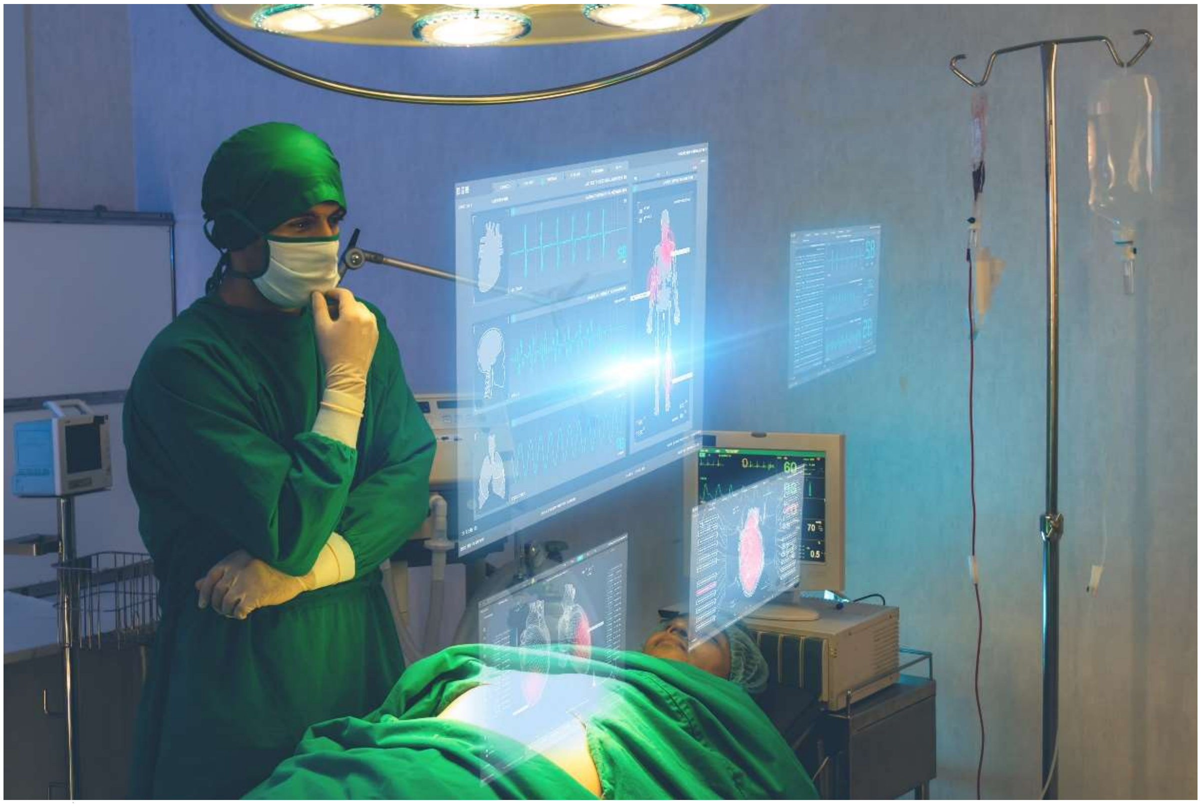
The healthcare system continues to be extremely traditional in its processes. [5] Its procedure and facilities have changed little over the past several years, leading to cost and structure issues. Furthermore, it is expected that the number of people in the world above the age of 65 is going to double to 1.5 billion by 2050 [8]. This is a population that will require additional monitoring and more real-time interactions from healthcare professionals, as the world is facing a shortage in medical experts. [4]

Urbanization is another hurdle deteriorating the existing healthcare system. A recent study reveals that areas with high population density ratios experienced accelerating spread of the COVID-19 virus, causing sudden and sharp increases in the number of people calling for medical help. [13] It should be noted that 1.2 million people across the European Union that died could have been saved through more effective healthcare. [17] Thus, technology in general and the digital twins specifically appear to offer potential solutions to some of these challenges.

Emergence of The Digital Twin

The digital twin has emerged as one of digital transformation's innovative creations. In 2002, Michael Grieves of the Florida Institute of Technology enlightened the world with a concept and a model for a digital twin in manufacturing (specifically used in Product Lifecycle Management). [2] Grieves' preliminary approach was not extensively elaborated on until 2010, when NASA created the first practical digital twin in hopes of strengthening the physical models of spacecrafts through immense simulations and testing.

A digital twin is more than just a digital model. Digital twins are made up of the physical real object, its virtual digital representation, and the data connection between the two. Data is fetched from the physical object through sensors or other IoT devices and fed to its digital model. What distinguishes a digital twin is its dynamicity; the replica is constantly being updated and synchronized with the real physical object. [5] Higher accuracy and resemblance are achieved by increasing the amount of data being fed. This has a crucial effect on the results of the simulation, maintenance, and even predictions carried out by the digital twin.



The digital twin is witnessing a growth in popularity, including in the medical industry. Medical errors are the third leading cause of death [9], so finding safer strategies that can minimize this dilemma is imperative. Experts and researchers have expressed their confidence that the digital twin will continue to improve as a diagnosis and treatment tool. [5] Healthcare officials are expecting an increase in investment of 66% in the use of the digital twin over the next three years. [3]

Benefits and Opportunities

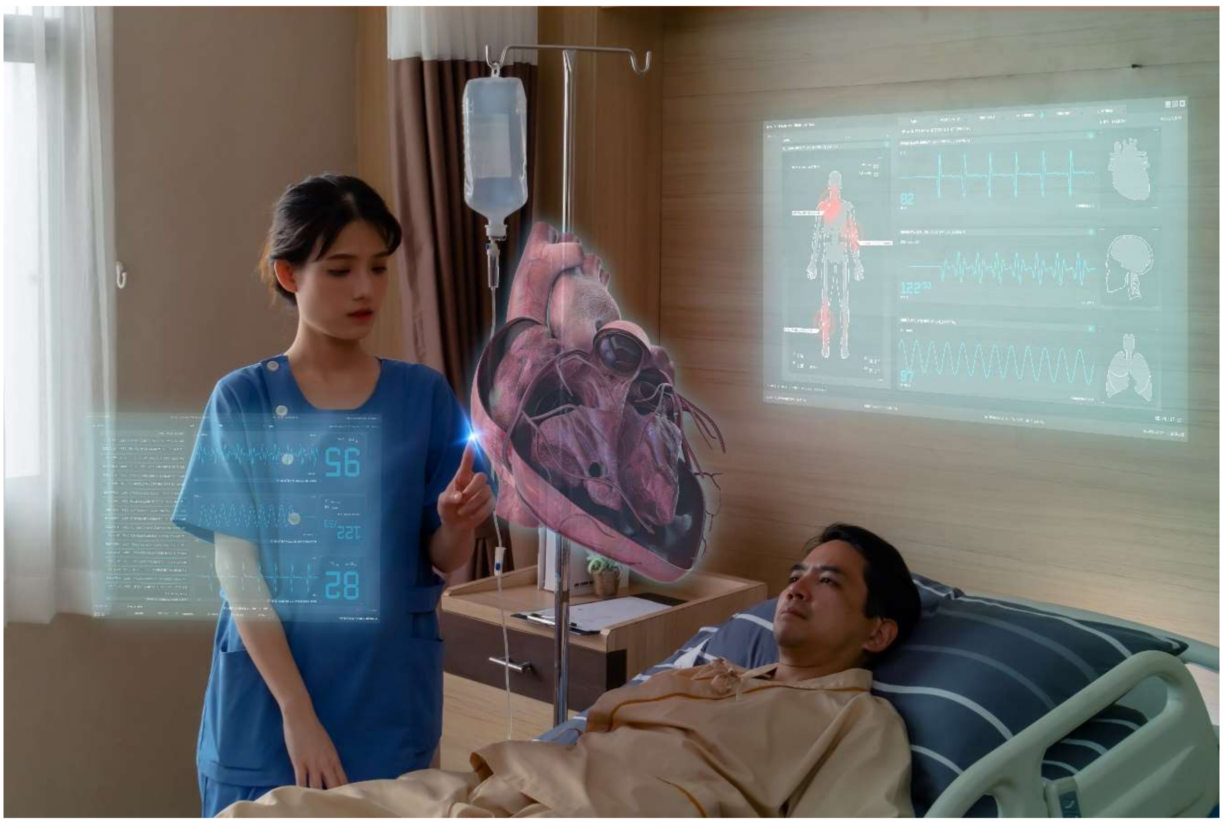
One of the major benefits of the digital twin in the healthcare industry is equality in the treatment of patients, helping to reduce bias in consultations. [5] The digital twin can collect, store, analyze and compare data with little to no intervention in the daily routine of the patient. With the assistance of wearable sensors and other IoT devices, data can smoothly and invisibly be gathered. Another benefit of the digital twin is reducing the necessity of in-person medical consultations and the lengthy wait for a person's response to a treatment. [4] An automated system can drive much of the medication process, including medicinal dosages and treatment plans.

Cost is another area where the digital twin can provide benefits. The cost of medical services is considerably high worldwide. For example, the cost of diabetes care alone was $245 million in 2016, and it has increased around 20% in the last few years. [14] The high accuracy that the digital twin brings using simulations significantly decreases the possibility of an incorrect diagnosis; treatments are shorter in time and more effective leading to a reduction in cost. [5] Another aspect in cost is dealing with some of the less urgent cases outside the physician's clinic. This act paves the way for another socio-ethical benefit: supporting the patient's autonomy to make their own decisions by self-diagnosis, consequently reducing the burden off the physician's shoulders. For example, patients suffering from a chronic disease do not need to visit the hospital nor the doctor constantly – their treatment can be applied at home. This gives patients a sense of responsibility and independence from the frequent medical appointments.

Another major benefit that the digital twin provides to the medical field is predictive analysis. Historically, the healthcare system has a reactive nature where medical services are typically provided to patients only after they show symptoms. The early detection of illnesses is "a change in the societal culture" as it promotes the individual to proactively address and maybe even avoid their illness. [6] A highly accurate digital twin prediction model, using a neural network algorithm, has been developed to diagnose Parkinson's disease by analyzing a patient's voice recording. [4] Calculating the disease risk and its probability is directly related to two important types of data: real-time and historical data. Real-time data represents the continuous feed from wearable sensors. Historical data comprises the person's age, family tree, and previous record with illnesses. The digital twin gives healthcare specialists the chance of performing direct simulations on the dynamic and digital replica of the person to understand different treatment options and their effectiveness. They add a predictive approach to diagnosis enabling preventive healthcare, a credible and effective risk assessment and evaluation, and an extra insight with the help of artificial intelligence.

Smart Healthcare and Personalized Medicine

Smart healthcare is highly dependent on dynamic data and its connectivity with IoT devices. In fact, smart healthcare has initiated a specific category of IoT called IoMT (Internet of Medical Things) to differentiate the devices used in the medical field from others. With the continuous advancement in technology, these devices are growing in number and variety while decreasing in cost, which is facilitating their widespread deployment. Recently, a 42-year-old was admitted to the hospital with a seizure. Doctors resorted to his Fitbit Charge HR fitness tracker to



see his latest vital signs (heart rate, body temperature, and blood pressure). These gathered statistics were heavily relied on as they helped doctors decide the patient's treatment plan. [10]

Another example of smart healthcare is the virtual hospital. Patients are equipped with home monitors that track their vital signs to indicate their overall health condition. These indicators are monitored by artificial intelligence and doctors that can easily order the patients to admit themselves to the real hospital if necessary. With smart healthcare emerged personalized medicine – a medical treatment customized specifically for an individual patient. The benefit behind personalized medicine is that it offers the shortest and most effective treatment for the patient as it was designed exclusively for them. The digital twin can investigate the impact of different medications and drugs on the body by simulating them prior to usage.

Implementation Challenges

Privacy represents the first major obstacle for technology in the healthcare field. Given that the technology is still in its developing stage, there is a lack of established standards and protocols. This creates uncertainty for people as they are unsure who is supervising their real-time data and raises the concern of data theft. [17] Moving forward, most approaches are focused on finding a compromise between the societal benefits and personal privacy.

Aside from privacy concerns, tracking real-time information from an operational human body is a difficult task to accomplish. There is huge complexity associated with correlating the vast amount of data gathered. IoMT devices stream data continuously which places an additional burden on IT departments and data clouds. This increases computational and latency issues, especially when dealing with a large number of people. The data to perform an adequate treatment plan, predictive analysis, and risk evaluation needs to be automated and filtered out in order to improve the efficiency of the process. [4]

Final Thoughts

In hopes of overcoming these challenges, several items are key. While regulatory protections will help, businesses will still need to employ transparency. As healthcare companies shift to cloud-based systems, robust data governance practices will be required. Through data governance, data is held privately until administrators permit access of medical experts to certain data at specific times. [7] Finally and probably most importantly, patients will increasingly need a level of digital literacy to understand what is happening to their data.

References

[1] *History of digital transformation*. Capacity. (2021, August 27). Retrieved June 27, 2022, from https://capacity.com/digital-transformation/history-of-digital-transformation/#:~:text=Yet%2C%20it%20was%20in%202013,a%20response%20to%20changing%20times

[2] *What is Digital Twin Technology and how does it work?* TWI. (n.d.). Retrieved June 27, 2022, from https://www.twi-global.com/technical-knowledge/faqs/what-is-digital-twin

[3] *Best Digital Twin Applications & Use Cases in healthcare in 2022*. AIMultiple. (n.d.). Retrieved June 27, 2022, from https://research.aimultiple.com/digital-twin-healthcare/

[4] Volkov, I., Radchenko, G., & Tchernykh, A. (2021). Digital Twins, internet of things and mobile medicine: A review of current platforms to support Smart Healthcare. *Programming and Computer Software*, *47*(8), 578–590. https://doi.org/10.1134/s0361768821080284

[5] Popa, E. O., van Hilten, M., Oosterkamp, E., & Bogaardt, M.-J. (2021). The use of Digital Twins in healthcare: Socio-ethical benefits and socio-ethical risks. *Life Sciences, Society and Policy*, *17*(1). https://doi.org/10.1186/s40504-021-00113-x

[6] Ahmadi-Assalemi, G., Al-Khateeb, H., Maple, C., Epiphaniou, G., Alhaboby, Z. A., Alkaabi, S., & Alhaboby, D. (2020). Digital Twins for Precision Healthcare. *Advanced Sciences and Technologies for Security Applications*, 133–158. https://doi.org/10.1007/978-3-030-35746-7_8

[7] Digital Twins in healthcare: Conceptualisation and privacy aspects - project library, Aalborg University. (n.d.). Retrieved June 27, 2022, from https://projekter.aau.dk/projekter/en/studentthesis/digital-twins-in-healthcare-conceptualisation-and-privacy-aspects(4bbbfe99-f074-493e-839c-0efab7c6d192).html

[8] *World population ageing 2019: Highlights - United Nations*. (n.d.). Retrieved June 27, 2022, from https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Highlights.pdf

[9] Makary, M. A., & Daniel, M. (2016). Medical error—the third leading cause of death in the US. *BMJ*, i2139. https://doi.org/10.1136/bmj.i2139

[10] Rudner, J., McDougall, C., Sailam, V., Smith, M., & Sacchetti, A. (2016). Interrogation of patient smartphone activity tracker to assist arrhythmia management. *Annals of Emergency Medicine*, *68*(3), 292–294. https://doi.org/10.1016/j.annemergmed.2016.02.039

[11] Anita, S., & Aruna Priya, P. (2016). Early prediction of parkinson's disease using artificial neural network. *Indian Journal of Science and Technology*, *9*(36). https://doi.org/10.17485/ijst/2016/v9i36/98401

[12] Liu, Y., Zhang, L., Yang, Y., Zhou, L., Ren, L., Wang, F., Liu, R., Pang, Z., & Deen, M. J. (2019). A novel cloud-based framework for the elderly healthcare services using Digital Twin. *IEEE Access*, *7*, 49088–49101. https://doi.org/10.1109/access.2019.2909828

[13] Carozzi, F. (2020). Urban density and covid-19. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3643204

[14] Economic costs of diabetes in the U.S. in 2012. (2013). *Diabetes Care*, *36*(4), 1033–1046. https://doi.org/10.2337/dc12-2625

[15] Mannix, L. (2020, March 29). *Australia's first virtual hospital rolls out for COVID-19 patients*. The Sydney Morning Herald. Retrieved June 27, 2022, from https://www.smh.com.au/national/australia-s-first-virtual-hospital-rolls-out-for-covid-19-patients-20200329-p54ezj.html

[16] Björnsson, B., Borrebaeck, C., Elander, N., Gasslander, T., Gawel, D. R., Gustafsson, M., Jörnsten, R., Lee, E. J., Li, X., Lilja, S., Martínez-Enguita, D., Matussek, A., Sandström, P., Schäfer, S., Stenmarker, M., Sun, X. F., Sysoev, O., Zhang, H., & Benson, M. (2019). Digital Twins to personalize medicine. *Genome Medicine*, *12*(1). https://doi.org/10.1186/s13073-019-0701-3

[17] OECD Publishing. (2018). *Health at a glance: Europe 2018: State of Health in the Eu cycle*.

About the Author

Sary Yehia

Sary Yehia is an Electrical Engineering Honors student at the Lebanese American University - LAU. He hopes to pursue an advanced degree in an area of interest, which includes biotechnology and power systems.