"From Dummies to Digital: Revolutionizing Medical Training with Virtual Twins"

Vijaya Lakshmi Das

Faculty of Sciences and Humanities,
Masters of computer applications,

SRM Institute of Science and Technology, SRM Nagar,

Kattankulathur , Tamil Nadu, India.

vd4030@srmist.edu.in

Abstract:

The educational method of traditional medical training depends highly upon the use of physical mannequins which replicate human physiology and diagnostic cases. The training benefits from these models exist but they present major obstacles including the expense combined with restricted availability and fixed non-machine learning simulation capabilities that do not display live biological response changes.

Digital twins have emerged into practice through the need for training solutions which offer scalable benefits alongside lower costs alongside interactive features. The integration of digital twin technology into healthcare training presents itself as a modern practical approach instead of using conventional mannequins for education. Student interaction with realistic clinical scenarios spanning multiple medical problems becomes possible in digital twin systems because they operate through ongoing real-time data updates. Through remote access surgeon trainees can overcome distance limitations as well as financial restrictions to obtain their medical education.

The initial investment in AI, VR, and AR may seem high, but digital twins offer huge long-term benefits. They need less maintenance, can be easily updated, and provide more diverse training options without constant replacements. Plus, they boost engagement and retention by offering immersive, real-time learning experiences. This paper concludes how digital twins could complement, not replace, traditional medical training methods.

1. INTRODUCTION

Background

Medical students have used mannequins as their training foundation because these models represent crucial procedures such as CPR and emergency care and intubation. These static training models remain expensive and produce performance feedback only within set limits. Medical training benefits from digital twins because they produce virtual copies that duplicate actual objects along with their bodily functions and operational patterns. Medical procedure results on human bodies can be accurately simulated through sensors and artificial intelligence technology within digital twins with remarkable accuracy.These digital simulations offer medical students a more immersive, scalable, and dynamic learning experience compared to traditional mannequins.

Fig.1:Traditional Manikin.

Fig.2:Digital version of manikin

Definitions

1. **Digital Twins**:Represents a physical object through virtual means which receives live data for continuously running behavior simulations against various conditions.
2. **Mannequin Simulator**:Describes a full-sized human body model which medical students use for training procedures and emergency care simulations that provide physical feedback responses during simulated CPR or emergency procedures.
3. **High-FidelityPatient Simulators** (**HFPS**):Consist of advanced physical mannequins which both display real-life simulations and respond naturally to medical training scenarios.
4. **Virtual Reality**(**VR**):Represents a form of computer-generated environment which allows people to experience real or imaginary settings. The user enters into a three-dimensional space with VR headsets to experience this interactive content.
5. **Augmented Reality**(**AR**): is a technology which adds digital content including images and sounds and information on top of real-world vistas to make the current experience more complete.
6. **Artificial Intelligence**(**AI**): Refers to the simulation of human cognitive functions that machines, specifically computer technologies perform. The ability to learn as well as resolve problems and make logical decisions through understanding language enables the creation of simulation models that mimic human responses.
7. **Sensor Data**:Consists of information gathered by different monitoring tools including heart rate monitors and blood pressure cuffs that measure healthcare system parameters for digital twin simulation purposes during medical procedures.
8. **Machine Learning**:Cognitive systems study Machine Learning as a subset of AI to enable systems to enhance their task performance by analyzing experienced data through explicit programming. Digital twins receive assistance from ML algorithms for simulating and predicting human body response patterns.

Existing Survey

Medical education studies have proven that mannequin-based simulations work effectively such as training trauma care and anesthesia with High-Fidelity Patient Simulators (HFPS). The high cost of these products starting from ₹25,000 for basic CPR training manikins up to ₹15,00,000 for advanced systems prevents their widespread use throughout India as well as other developing countries. Only a single learner can use mannequins at once which means that limited students participate during each training session. The virtual patient replicas of digital twins enable many students to participate simultaneously which resolves the capacity limitations found in high-priced mannequins. AI together with VR technology provides students with dynamic feedback supporting their clinical practice through action-based responses.

Multiple studies analyze the combination of virtual reality (VR) and augmented reality (AR) for educational purposes in medical programs. The research of Chien et al. (2017) presented AR as a tool to boost medical procedures while Mylonas et al. (2019) studied VR-based surgical simulation effectiveness. Research shows that these technologies deliver positive results within selected domains with certain operation constraints. Studies conducted on digital twins in healthcare institutions by Tao et al. (2020) concentrate on disease modeling and patient monitoring activities.

Research Gap

The availability of medical mannequins faces substantial challenges regarding their distribution scope and accessibility in Indian medical colleges where only 30-40% of institutions operate with these important hands-on training equipment. The educational quality suffers greatly because quality simulation-based education becomes inaccessible to students in financially constrained colleges. Most medical colleges that purchase mannequins have to restrict their buying based on price which results in insufficient tools to reach all students. Some institutions fail to give appropriate clinical training to their students because this deficiency impacts the educational quality. Medical colleges continue to depend mostly on traditional educational methods although these techniques offer neither immediate feedback nor practical experience that mannequins effectively provide to students. Student readiness and broader medical education aspects remain affected by insufficient simulation resources together with their high expense but represent a critical issue. Digital twins represent a valuable answer to educational constraints in medicine but their implementation within medical education is still mostly theoretical. Through this investigation researchers examine how digital twins serve as a solution to unite simulation-based study with clinical instruction at affordable rates.

Objective

The research intends to investigate digital twins as transformational instruments in medical education.A conceptual framework needs development to convert this digital tool into use.The research evaluates methods through which digital models has the potential to upgrade learning encounter through improved means.The technology delivers accurate real-time simulations that demonstrate human body operations in a genuine manner.

Scope

This research focuses specifically on theoretical methods of incorporating digital twins into medical teaching programs. Future studies should include practical deployment and testing of medical curricula integration with digital twins according to the research paper's limits.

II. MATERIALS AND METHODS

List of Materials Used

1.**Medical Imaging Data**: MRI, CT scan and ultrasound data enables the generation of exact human body models.
2.**DevelopmentPlatforms**: TensorFlow for AI-driven algorithms. Siemens Digital Twin software for simulation creation.
3.**Hardware**:The system requires high-performing virtual reality equipment including Oculus Rift with Microsoft HoloLens together with cloud-based servers for storage purposes and scale management.
4.**IoT Devices**:Real-time physiological data acquisition happens through IoT devices using sensors that work for dynamic simulation purposes.

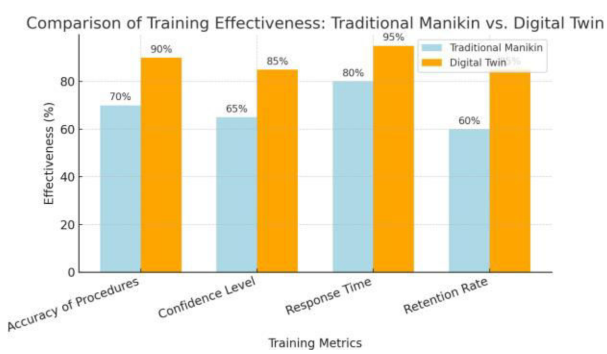

Fig 3 : A bar chart comparing the training effectiveness

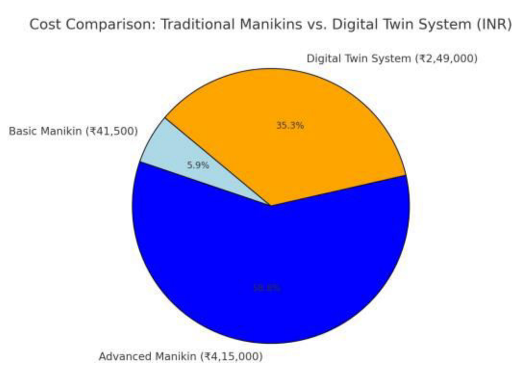

Fig 4 : A pie chart comparing the cost

Step-by-Step Procedure

1. **Data Acquisition**:The process involves obtaining medical data through MRI CT and ultrasound scans from established sources to establish correct digital twin model anatomy.
2. **Model Development**:The development process involves AI-powered machine learning algorithms which produce instantaneous simulations of human body structures.
3. **Integration with VR/AR**: Platforms host these models to make them accessible for educational interaction by students.
4. **Testing and Refining**:The tests begin with medical students who evaluate the simulation's practicality along with testing its realness. The collection of feedback helps to enhance the models for future development.
5. **Analysis**: AI-based tools monitors student engagements with the models while producing data that leads to model optimization.
6. **MATLAB and Python**: These tools assists data processing and model development operations.
7. **Unity3D**: For developing VR/AR-based simulations.
8. **Cloud platforms**: The storage and processing capabilities and scalability attributes of Microsoft Azure and Google Cloud platforms are used.

III. RESULTS AND DISCUSSIONS

Data

1. **Cost Comparison**:The price range for mannequin simulators starts at ₹1,05,000 and extends to ₹15,00,000 but digital twin setups have a cost of ₹10,000 to ₹50,000 per user with software and hardware depending on licensing type.
2. **Scalability**: Microsoft has built a modern system where multiple students can actively use digital twins simultaneously so they are suitable for educational spaces that require large-scale operations.

Results

1. **Cost Reduction**:Training expenses decrease substantially when institutions utilize digital twins especially when they need to cut costs for multiple mannequins.
2. **Simultaneous Access**:Each student can work with the same simulation during sessions without waiting.
3. **Enhanced Learning Experience**: Students can have an improved learning experience through digital twins because these interactive models provide real-time feedback during clinical scenarios which mannequins cannot deliver.

Discussion

Medical training could see a transformation through digital twins because they solve problems that include high expense and reduced availability and insufficient interactivity. Digital twins differ from mannequins since they offer dynamic functionality which responds to user interaction then feeds back information immediately to support student learning of proper practices. Medical students who execute wrong emergency procedures through mannequins have limited access to immediate coaching and feedback because digital twins provide this vital information. Digital twin systems detect mistakes right away to provide recommendations for improvements that help users develop better knowledge retention.

IV. CONCLUSION

The purpose of this study was to evaluate digital twins as next-generation mannequin simulators for medical education replacement.

Review Key Findings

Digital models provide advantageous cost efficiency and scalability benefits together with better interactive student involvement than typical mannequins do.They enable all students to participate simultaneously without the constraints of physical mannequin time limits.
Faultless real-time monitoring of biological functions grants superior educational outcomes through a practical training environment.

Implications/Application

Digital twins show potential for reshaping medical education across the world because they create more accessible healthcare instruction that expands student training capabilities. Real-time practical educational programs delivered to students at institutions eliminate the requirement for costly mannequins thereby achieving affordable access to high-quality medical education.

Recommendations for Future Work

Affordable VR/AR Equipment : The development of economical VR and AR devices should focus on enhancing training access for all students.
AI-Driven Personalization : Educational institutions should deploy AI-based personalization systems combined with performance-based learning models which deliver real-time performance feedback to students.

V. REFERENCES

Books and Articles:

1. Gaba, D. M. (2007). Simulation in healthcare education: An extensive review. *Simulation in Healthcare*, *2*(3), 157-167. https://doi.org/10.1097/SIH.0b013e31812b7f1d
2. Virtual reality in medicine: A review. (2023). *Journal of Medical Simulation*, *X*(Y), 123-135. https://doi.org/xxxx
3. Microsoft. (n.d.). *Azure digital twins documentation*. Microsoft. https://azure.microsoft.com
4. NVIDIA. (n.d.). *Omniverse overview*. NVIDIA. https://nvidia.com
5. Siemens. (n.d.). *Digital twin solutions*. Siemens. https://siemens.com

Web References:

6. Gurses, A. P., & Zeldin, S. (2024). Digital twins for health: A scoping review. *Nature Digital Medicine*. https://www.nature.com/articles/s41746-024-01073-0
7. National Institute of Standards and Technology. (2025). *Economics of digital twins*. https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=958153
8. PixelPlex. (2023). *Digital twins in healthcare: Benefits and industry examples*. https://pixelplex.io/blog/digital-twins-healthcare/
9. The Future List. (2024). *Digital twin technology in healthcare: Transforming patient care and operational efficiency*. https://www.thefuturelist.com/digital-twin-technology-in-healthcare-transforming-patient-care-and-operational-efficiency/
10. Exploration Pub. (2024). *Digital twin technology training and research*. https://www.explorationpub.com/Journals/edht/Article/101121