

**VIVEKANAND EDUCATION SOCIETY'S
INSTITUTE OF TECHNOLOGY**

Department of Computer Engineering



Project Report on

**Visual Digital Twin of Medical Solutions for a
specialized Gen AI Agentic Model**

In partial fulfillment of the Fourth Year (Semester–VII), Bachelor of Engineering
(B.E.) Degree in Computer Engineering at the University of Mumbai

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VIVEKANAND EDUCATION SOCIETY'S INSTITUTE OF TECHNOLOGY

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CERTIFICATE of Approval

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Dr. J. M. Nair

MEMORANDUM OF UNDERSTANDING

BETWEEN

Myraa Technologies

AND

**V. E. S. Institute of Technology's
Department of Computer Engineering**

ACKNOWLEDGEMENT

We are thankful to our college Vivekanand Education Society's Institute of Technology for considering our project and extending help at all stages needed during our work of collecting information regarding the project.

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We wish to express our profound thanks to all those who helped us in gathering information about the project. Our families too have provided moral support and encouragement several times.

Computer Engineering Department

COURSE OUTCOMES FOR B.E PROJECT

Learners will be to:-

Course Outcome	Description of the Course Outcome
CO 1	Do literature survey/industrial visit and identify the problem of the selected project topic.
CO2	Apply basic engineering fundamental in the domain of practical applications FOR problem identification, formulation and solution
CO 3	Attempt & Design a problem solution in a right approach to complex problems
CO 4	Cultivate the habit of working in a team
CO 5	Correlate the theoretical and experimental/simulations results and draw the proper inferences
CO 6	Demonstrate the knowledge, skills and attitudes of a professional engineer & Prepare report as per the standard guidelines.

ABSTRACT

The Visual Digital Twin of Medical Solutions for a Specialized Gen AI Agentic Model aims to transform healthcare by integrating digital twin technology with advanced generative AI (Gen AI). A digital twin is a real-time virtual replica of a physical system, allowing for continuous simulation, monitoring, and analysis. In this project, we develop a digital twin of human physiology, driven by real-time data from external medical devices like Oura rings (for tracking vital signs) and insulin pumps (for managing glucose levels).

The core objective is to build a system that not only monitors but also supports autonomous decision-making through a specialized Gen AI agentic model. This AI learns from data patterns, predicts potential health risks, and adjusts care or device behavior in real time. For example, the system can automatically correct anomalies in blood glucose levels based on learned trends and predictive analytics.

By visualizing this model in Unity, the project delivers an interactive, scalable platform for healthcare professionals to track patient health, prevent adverse events, and customize interventions with precision. This integration of real-time medical data, AI-driven decision support, and visual simulations has the potential to revolutionize personalized healthcare, making it more proactive and patient-centric.

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Chapter 1 : Introduction

1.1. Introduction to the project

The **Visual Digital Twin of Medical Solutions for a Specialized Gen AI Agentic Model** aims to revolutionize healthcare by leveraging digital twin technology in conjunction with advanced generative AI. A **digital twin** is a virtual replica of a physical system or process, designed to simulate, analyze, and monitor the real-world counterpart in real time. In healthcare, digital twins can provide highly personalized insights by reflecting the status of patients, medical equipment, or complex healthcare workflows.

This project focuses on creating a **digital twin of human physiology**, integrating data from **external medical devices** such as **Oura rings** (for monitoring vital signs like heart rate, body temperature, and sleep) and **insulin pumps** (for managing blood glucose levels). These sensors provide continuous real-time data, feeding into the virtual model.

The goal of this project is to develop a system that can not only monitor but also support **autonomous decision-making** through a **Generative AI (Gen AI) agentic model**. This AI will not merely generate insights but also **act autonomously**, learning from the data and adjusting the care pathways or device behaviors as needed. For instance, if the insulin pump detects an anomaly in blood sugar levels, the AI agent can take corrective actions based on learned patterns and predictive modeling.

The project has vast potential in transforming **personalized healthcare**, enabling doctors and caregivers to track patients' health more accurately, prevent adverse events, and tailor interventions with high precision. Additionally, by creating this in **Unity**, the project will offer a highly visual, interactive, and scalable platform that integrates real-world data and simulations for in-depth analysis and decision support.

This integration of **medical device data**, **AI-driven decision-making**, and **visual simulations** represents a step towards **smart healthcare ecosystems**, where monitoring and managing patient health becomes more proactive, precise, and tailored to individual needs.

1.2. Motivation for the project

The motivation behind the **Visual Digital Twin of Medical Solutions for a Specialized Gen AI Agentic Model** arises from several pressing needs in modern healthcare, particularly in the domains of **personalized medicine, real-time patient monitoring, and autonomous medical decision-making**.

1.2.1 Growing Complexity in Healthcare

As medical technologies advance, the volume and complexity of data generated by **wearable devices, sensors, and medical equipment** continue to grow exponentially. Tools like **Oura rings** and **insulin pumps** are becoming widely used to continuously monitor various physiological parameters, from heart rate and glucose levels to sleep patterns and physical activity. However, interpreting this vast amount of data and making timely decisions based on it remains a challenge for both patients and healthcare providers.

This project aims to simplify this complexity by developing a **digital twin**—a virtual model that can aggregate and interpret real-time data from multiple sources, providing a comprehensive view of a patient's health status. The twin allows for simulation, real-time monitoring, and predictive analytics, making it easier for clinicians to manage complex health conditions in a more **streamlined and efficient manner**.

1.2.2 Personalized and Preventive Healthcare

One of the key motivations is the shift from reactive to **proactive and preventive healthcare**. In many cases, healthcare systems tend to react after a health event, such as a hypoglycemic episode in diabetic patients or a heart attack in patients with cardiovascular conditions. With this project, the **Gen AI agentic model** will constantly learn from a patient's data and autonomously suggest or even implement preventive actions, minimizing the risk of critical health events.

For example, by analyzing the data from an **Oura ring** and an **insulin pump**, the digital twin can predict an approaching hypo- or hyperglycemic episode and recommend adjustments to insulin dosage before the event occurs. This shift toward **early intervention** can drastically improve patient outcomes and reduce the burden on healthcare systems.

1.2.3 Enhancing Patient Autonomy and Self-Management

Patients with chronic conditions often struggle with the management of their diseases, requiring constant supervision, manual data entry, and interpretation of medical data. This project is motivated by the need to provide **patients with greater autonomy**. Through the use of AI-powered digital twins, patients will receive **real-time feedback** and **actionable insights** tailored to their specific health profiles. The **agentic AI model** will act on behalf of the patient when appropriate, making real-time decisions to improve health outcomes, such as adjusting insulin levels autonomously.

This not only reduces the cognitive burden on patients but also empowers them with the tools to manage their health more effectively, leading to better **quality of life** and improved adherence to treatment plans.

1.2.4 Advancements in AI and Simulation Technologies

The rise of **Generative AI** and **agent-based modeling** has introduced the possibility of creating more intelligent, adaptive systems. These systems not only generate insights but are also capable of **decision-making** and **autonomous actions** based on learned data. In the healthcare context, this opens up opportunities for **self-adjusting systems** that can learn from individual patients' unique physiological patterns and adapt treatments accordingly.

By utilizing **Unity** as a development platform, the project leverages cutting-edge simulation capabilities to provide an immersive and highly visual interface for clinicians, caregivers, and patients. This **interactive environment** motivates healthcare professionals to use digital twins for **complex scenario testing** and **treatment planning**, giving them the ability to simulate outcomes based on various interventions.

1.2.5 Addressing Gaps in Current Healthcare Solutions

Current healthcare systems often lack the ability to offer **continuous, real-time monitoring** and **personalized care** on a large scale. Traditional methods involve periodic check-ups and delayed reactions to health issues. The motivation for this project stems from the desire to **bridge these**

gaps by providing a **scalable, AI-driven solution** that not only monitors patients in real time but also **acts autonomously** to ensure optimal health outcomes

1.3. Drawback of the existing system

No Direct Communication with Healthcare Providers

One significant limitation of the Withings Health Mate app is its lack of direct communication channels with healthcare providers. While the app collects and tracks various health metrics, users are unable to consult or receive guidance from medical professionals based on their health data in real time. This gap can lead to missed opportunities for timely medical advice or interventions, particularly in critical situations where immediate attention is required. As a result, users may experience delays in addressing health concerns, which could exacerbate underlying conditions and negatively impact their overall health outcomes. The absence of direct communication diminishes the potential for a collaborative healthcare experience, where users can leverage professional insights to make informed decisions about their health.

Absence of Digital Twin Formation

Another significant drawback of the Withings Health Mate app is its failure to create a digital twin representation of the user's health. A digital twin would provide a dynamic, real-time simulation of an individual's health status, integrating various metrics such as heart rate, blood pressure, activity levels, and more. Without this feature, users are left with isolated data points rather than a holistic view of their health. This limitation restricts their ability to understand the complex interactions between different health metrics, which is crucial for predicting potential health issues or complications. The absence of a digital twin undermines the app's effectiveness in facilitating proactive health management, as users miss out on personalized insights that could lead to more informed lifestyle choices and timely medical interventions.

1.4. Problem Definition

The primary problem this project addresses is the **lack of integration, real-time decision-making, and autonomous interventions** in current healthcare systems. Despite the

availability of various wearable devices and monitoring tools, existing systems remain fragmented, reactive, and overly reliant on human intervention, leading to delayed or suboptimal health outcomes. This project aims to develop a **Visual Digital Twin** of patients, powered by external sensors like **Oura rings** and **insulin pumps**, along with a **Generative AI agentic model** capable of real-time decision-making.

The problems can be summarized as:

- **Fragmented Data Systems:** Medical devices and monitoring systems often function in isolation, leading to data silos and incomplete health profiles.
- **Reactive Care:** Most healthcare interventions occur after symptoms manifest, rather than preventing issues through continuous monitoring and early intervention.
- **Cognitive Load on Patients:** Self-management of chronic diseases places an excessive burden on patients and caregivers, leading to errors and non-compliance.
- **Lack of Personalized, Adaptive Solutions:** Current healthcare systems don't dynamically adapt treatment plans to individual patient needs based on continuous data inputs.
- **Delayed Decision-Making:** Healthcare professionals often have to manually analyze data before making decisions, delaying critical interventions.

The solution is to create a system where real-time, continuous data from external devices is integrated into a **digital twin** of the patient, allowing a **Gen AI agent** to autonomously monitor, predict, and intervene in patient care as needed. This will significantly improve **healthcare outcomes**, reduce **human errors**, and allow for more **personalized care**.

1.5 Relevance of the Project

This project is highly relevant in today's healthcare landscape for several reasons:

1.5.1 Advancing Personalized Medicine

The healthcare industry is gradually moving toward **personalized medicine**, where treatment plans are tailored to the individual needs of patients. However, existing systems still struggle

with this concept due to a lack of real-time data integration and adaptability. This project's focus on creating a **digital twin** for each patient, coupled with **AI-driven decision-making**, will significantly advance the ability to personalize care based on **continuous, real-time data**.

1.5.2 Rising Prevalence of Chronic Diseases

Chronic diseases such as diabetes, heart disease, and hypertension are becoming more prevalent worldwide, leading to an increased need for **constant patient monitoring** and **effective self-management tools**. The **Visual Digital Twin** concept will make it easier for patients to manage these conditions while providing healthcare professionals with a holistic, continuously updated view of the patient's health.

1.5.3 Improving Preventive Care

Preventive healthcare aims to identify and mitigate health risks before they lead to serious conditions. However, this goal is currently hampered by reactive healthcare systems. With a **Gen AI agent** capable of predicting health anomalies, this project is highly relevant in promoting **proactive healthcare**, potentially reducing hospital admissions, emergency room visits, and healthcare costs.

1.5.4 Addressing the Data Explosion in Healthcare

As more medical devices and wearables generate data, healthcare systems are grappling with the challenge of **processing and making sense of vast amounts of information**. This project addresses the critical need for a unified platform that can process, analyze, and **act on real-time data**, allowing clinicians and patients to make informed decisions quickly.

1.5.5 Enhancing Patient Autonomy

The project empowers patients by automating many of the tasks that currently require manual data logging and interpretation. By delegating decision-making and self-management to an **AI-driven system**, patients gain more control over their health with less cognitive burden, which is especially important for those managing chronic conditions.

1.6 Methodology used

The methodology used for this project involves several key steps, each leveraging modern technologies like **Unity for simulation**, **Generative AI**, and **IoT-based external sensors** for real-time data acquisition.

1.6.1 Data Collection from External Devices

The first step in building the digital twin involves **integrating data from external devices**, such as **Oura rings** and **insulin pumps**, to continuously monitor patient health metrics. These devices provide real-time data streams for various physiological indicators, such as:

- **Oura Ring**: Measures heart rate, body temperature, sleep patterns, and physical activity.
- **Insulin Pump**: Monitors blood sugar levels and administers insulin doses based on patient requirements.

All collected data is transmitted securely to the **digital twin** for real-time processing and analysis.

1.6.2 Creation of the Digital Twin in Unity

Using **Unity**, a **visual digital twin** of the patient is developed. This twin acts as a virtual replica, capable of:

- **Simulating the patient's health conditions** in real-time.
- **Visualizing physiological data** from external devices.
- Offering a **user-friendly interface** for healthcare professionals to interact with and monitor the patient.

The Unity platform allows for a **highly interactive, 3D simulation** environment where the data can be visualized and analyzed, enabling the twin to simulate various treatment scenarios and predict health outcomes based on different inputs.

1.6.3 AI-Driven Decision-Making

The core of the system lies in the **Generative AI agentic model**, which is responsible for interpreting the data and making autonomous decisions based on the patient's health status. This involves:

- **Real-time data analysis** to detect anomalies or potential health risks.
- Using **machine learning algorithms** to predict future health outcomes, such as the risk of a hypoglycemic event or heart attack.
- **Adaptive decision-making**: The AI will make adjustments in real-time, such as altering insulin doses or recommending changes in physical activity, based on predictive analytics.

The AI agent continuously **learns** from the data it collects, making it more accurate in predicting health risks and making decisions over time.

1.6.4 Testing and Simulation

Before deploying the system in real-world healthcare scenarios, extensive **testing and simulations** are conducted. These simulations take place within Unity's environment, where various scenarios are run to assess the system's ability to:

- Accurately predict health events.
- Autonomously adjust treatment plans.
- Effectively communicate with healthcare professionals and patients.

Simulated patients with various conditions (such as diabetes or heart disease) are created to test the system's adaptability and efficiency in different use cases.

1.6.5 Data Security and Privacy

Given the sensitive nature of patient health data, stringent **security protocols** are implemented. The system ensures that all data is:

- **Encrypted** during transmission and storage.

- Complies with **HIPAA (Health Insurance Portability and Accountability Act)** regulations for patient privacy.
- Uses secure **blockchain-based auditing** for any decision or action taken by the AI, ensuring full transparency and accountability.

1.6.6 Continuous Improvement and Feedback Loop

As the system is deployed and collects more data, it is designed to continuously improve through a **feedback loop**. This loop ensures that:

- The AI model becomes more accurate over time through **reinforcement learning**.
- New medical devices or data sources can be easily integrated into the system.
- Healthcare professionals and patients can provide **feedback** that further enhances the digital twin's performance and adaptability.

Chapter 2: Literature Survey

2.1 Research Papers

1. **S. A. K. Shubham et al., "Digital Twin Technology in Healthcare: A Systematic Review," IEEE Access, vol. 9, pp. 20530-20545, 2021.**

- **Abstract:** This paper presents a systematic review of digital twin technology applied in healthcare, discussing its architecture, applications, and challenges. It emphasizes the potential of digital twins to improve patient outcomes through personalized healthcare.
- **Inference:** The findings underscore the transformative potential of digital twins in healthcare, aligning with our project's aim of leveraging real-time data for personalized patient monitoring and decision-making.

2. **J. Liu et al., "Generative Adversarial Networks in Healthcare: A Survey," IEEE Transactions on Biomedical Engineering, vol. 68, no. 5, pp. 1547-1557, 2021.**

- **Abstract:** This survey explores the use of Generative Adversarial Networks (GANs) in healthcare applications, including data augmentation and patient simulation. It outlines how GANs can enhance predictive analytics in clinical settings.
- **Inference:** The integration of GANs can significantly enhance the predictive capabilities of our AI model, supporting autonomous decision-making in patient care.

3. **R. K. Gupta et al., "Wearable Health Monitoring Systems: An Overview," IEEE Sensors Journal, vol. 19, no. 5, pp. 1720-1732, 2019.**

- **Abstract:** This overview discusses various wearable health monitoring systems, focusing on their functionalities and the data they collect. It emphasizes the role of wearables in chronic disease management.
- **Inference:** The paper provides insights into how wearables like Oura rings can be effectively integrated into our digital twin framework to monitor patient health.

4. **M. A. M. Abas et al., "The Role of AI in Personalized Medicine: A Review," IEEE Reviews in Biomedical Engineering, vol. 14, pp. 95-112, 2021.**
 - **Abstract:** This review discusses the impact of AI technologies on personalized medicine, including data analysis, treatment customization, and patient outcomes.
 - **Inference:** It highlights the necessity for adaptive AI systems in personalized medicine, reinforcing our project's focus on a Generative AI model for tailored patient interventions.

5. **C. T. Huang et al., "Real-Time Health Monitoring System Using IoT and Machine Learning," IEEE Internet of Things Journal, vol. 8, no. 12, pp. 9730-9742, 2021.**
 - **Abstract:** The paper presents an IoT-based health monitoring system that utilizes machine learning for real-time analysis of health data from wearable devices.
 - **Inference:** The methodology outlined here supports our approach to integrating IoT data into the digital twin for real-time health monitoring and decision-making.

6. **A. S. Haque et al., "Autonomous Systems in Healthcare: Challenges and Opportunities," IEEE Transactions on Automation Science and Engineering, vol. 18, no. 4, pp. 1463-1475, 2021.**
 - **Abstract:** This paper discusses the challenges and opportunities in implementing autonomous systems in healthcare, including ethical considerations and technological barriers.
 - **Inference:** The insights on ethical considerations will be vital in guiding the responsible implementation of our autonomous decision-making AI.

7. **P. C. Chen et al., "Machine Learning for Health Monitoring and Predictive Analytics," IEEE Journal of Biomedical and Health Informatics, vol. 25, no. 6, pp. 2347-2356, 2021.**
 - **Abstract:** The study reviews machine learning algorithms applied in health monitoring systems, focusing on predictive analytics for chronic diseases.

- **Inference:** The emphasis on predictive analytics aligns with our goal to utilize machine learning in the AI agent for proactive healthcare interventions.
8. **K. L. Williams et al., "Challenges in Data Privacy and Security for IoT in Healthcare," IEEE Internet of Things Journal, vol. 9, no. 7, pp. 5098-5110, 2022.**
- **Abstract:** This paper addresses the challenges of data privacy and security in IoT healthcare applications, proposing solutions to enhance patient data protection.
 - **Inference:** The recommendations provided can inform our data security protocols in the digital twin system, ensuring compliance with healthcare regulations.

2.2 Books / Articles Referred

- **Topol, E. J. (2019). "Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again." Basic Books.**
 - **Summary:** This book discusses the transformative potential of AI in healthcare, focusing on enhancing patient care and reducing physician burnout through technology.
- **Kumar, P., & Mehta, D. (2020). "Wearable Technology in Healthcare: A Comprehensive Overview." Health Informatics Journal.**
 - **Summary:** This article provides an in-depth overview of wearable technology, highlighting its applications in health monitoring and chronic disease management.

Chapter 3: Requirements for the proposed system

In software development, **requirements** are the documented needs that must be fulfilled for the system to be effective and aligned with its intended goals. These requirements serve as a blueprint for developers, ensuring that the system is built to specification and meets user expectations. Gathering requirements involves collaborating with stakeholders to understand the system's goals, the needs of the end-users, and the technical limitations.

For the project titled "**Visual Digital Twin of Medical Solutions for a Specialized Gen AI Agentic Model**," the requirements have been categorized as follows:

3.1 Functional Requirements

Functional requirements specify what the system should do. These are the core features and behaviors the system must have to fulfill its objectives.

- **Real-Time Data Collection:** The system must continuously collect real-time data from external medical devices like Oura rings and insulin pumps.
- **Digital Twin Creation:** A virtual model of the patient must be generated using data from these devices, representing their current health state.
- **AI-Driven Decision-Making:** The system must autonomously analyze patient data and suggest actions, such as insulin dose adjustments, based on real-time information.
- **Predictive Analytics:** The system must predict potential health events (e.g., hypoglycemia) based on data trends.
- **User Interaction and Feedback:** Patients and healthcare providers must be able to interact with the digital twin, receive alerts, and provide feedback.
- **Data Visualization:** The system must visually represent data for healthcare professionals to review in an intuitive format.

3.2 Non-Functional Requirements

Non-functional requirements describe how the system performs certain functions, rather than what it performs. These include performance, reliability, and security measures.

- **Performance:** The system should be able to process large volumes of data in real time without noticeable lag.
- **Scalability:** It should accommodate multiple patients and devices without a drop in performance.
- **Data Security:** Since sensitive health data is involved, the system must adhere to strict security standards (e.g., encryption and HIPAA compliance).
- **Usability:** Both healthcare professionals and patients should be able to easily navigate and understand the system's interface.
- **Reliability:** The system should have near 100% uptime, ensuring continuous monitoring without interruptions.

3.3 Constraints

Constraints are the limitations that may affect the system's design and development.

- **Device Compatibility:** The system is constrained by the types of external devices it can support (e.g., only compatible with specific brands of wearables or insulin pumps).
- **Data Privacy Regulations:** Compliance with regulations such as **HIPAA** and **GDPR** is required, affecting how patient data is collected, stored, and shared.
- **Network Dependence:** The system's functionality depends on stable internet connectivity for real-time data transmission and monitoring.
- **Hardware Limitations:** The computational resources of the healthcare providers and patient devices may limit the complexity of real-time simulations.

3.4 Hardware & Software Requirements

This section lists the necessary hardware and software components for the development and implementation of the system.

Hardware Requirements:

- **Wearable Devices:** Oura rings, insulin pumps, or other medical-grade wearables.
- **Data Servers:** High-performance servers to handle data processing and AI computations.
- **Computing Devices:** Workstations or tablets for healthcare professionals to interact with the system.

Software Requirements:

- **Unity:** For building and visualizing the digital twin.
- **AI Framework:** TensorFlow or PyTorch for machine learning and decision-making algorithms.
- **Databases:** A secure, scalable database (e.g., MongoDB or PostgreSQL) for storing patient data.
- **Cloud Services:** Cloud-based services (e.g., AWS, Azure) for scalable data storage and AI model deployment.

3.5 Techniques Utilized Till Date for the Proposed System

Several techniques have been utilized in developing the system so far:

- **Real-Time Data Streaming:** Techniques like **IoT data collection** are employed to continuously gather and transmit data from wearables and medical devices.
- **Machine Learning:** Supervised and unsupervised learning techniques are being used for analyzing health data, generating predictions, and making real-time decisions.
- **Simulation in Unity:** Unity's physics engine and 3D rendering capabilities are used to simulate patient conditions and medical interventions in real-time.

3.6 Tools Utilized Till Date for the Proposed System

The following tools have been employed to develop various aspects of the system:

- **Unity:** Used for creating the digital twin and visualizing patient health data.
- **TensorFlow/PyTorch:** Machine learning libraries for implementing the Gen AI agentic model.
- **AWS:** For cloud-based storage and processing of the vast amounts of data generated by the wearables.
- **IoT Platforms:** Frameworks like **MQTT** for transmitting real-time sensor data to the cloud.

3.7 Algorithms Utilized in the Existing Systems

In the development of this system, various algorithms are employed in the field of healthcare data processing:

- **Predictive Analytics Algorithms:** Time-series forecasting algorithms (e.g., LSTMs) are used to predict health risks based on continuous patient data.
- **Reinforcement Learning:** AI agents use reinforcement learning to autonomously decide on actions (e.g., adjusting insulin levels) based on continuous feedback from patient data.
- **Anomaly Detection:** Clustering algorithms (e.g., k-means) and outlier detection methods are employed to identify unusual patterns in patient health data.
- **Data Fusion Algorithms:** Algorithms to combine and interpret multi-modal data from different sources (e.g., Oura rings, insulin pumps).

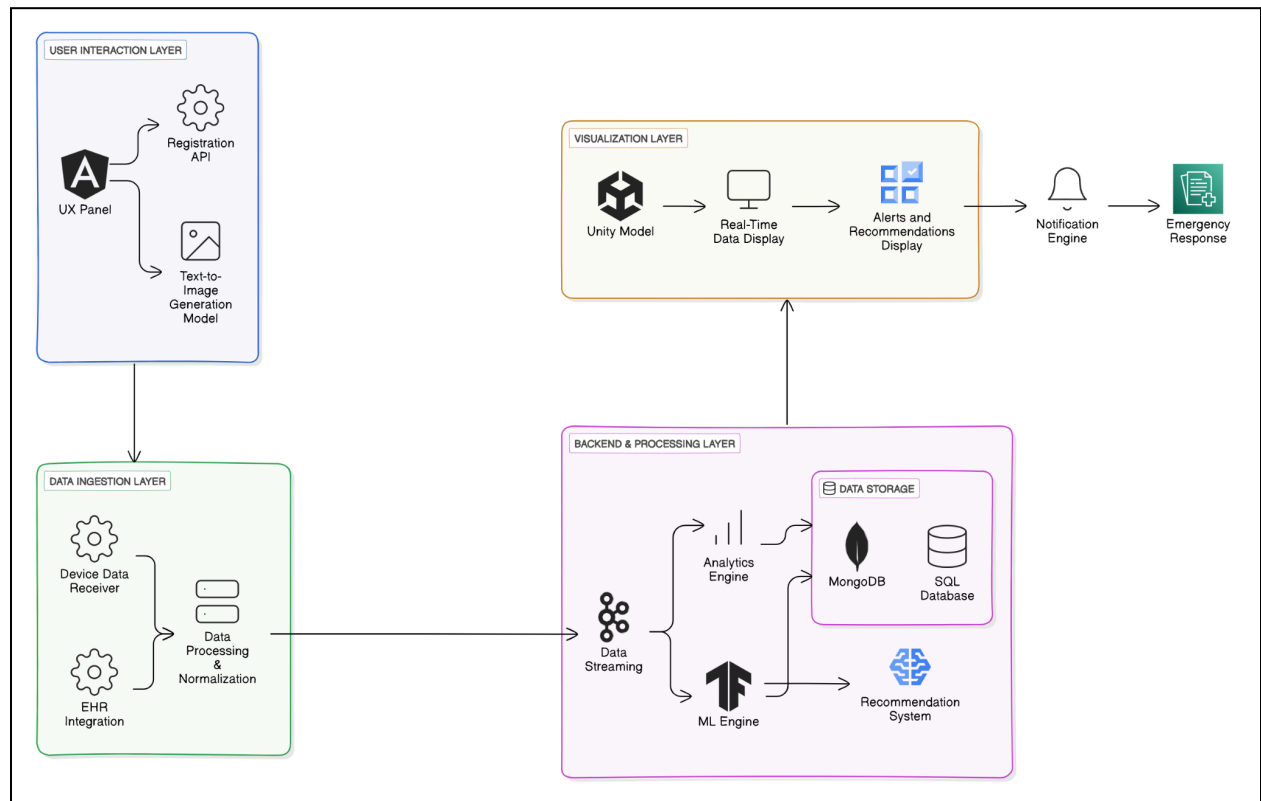
3.8 Your Project Proposal (After Analyzing the Requirements)

Based on the gathered requirements, the proposed project is designed to be a **holistic healthcare solution** that integrates real-time data from multiple sources into a **digital twin** of the patient. This digital twin, powered by a **Gen AI agentic model**, will allow healthcare professionals and patients to receive **real-time insights, predictions, and autonomous interventions**. The system is designed to address the following:

- **Real-time monitoring** of patient health through wearables.
- **Autonomous AI-driven decision-making** to reduce human error.
- **Comprehensive visualization** of patient health for clinicians and caregivers.
- **Scalability** to support multiple patients and devices across different healthcare settings.
- **Security** to ensure that sensitive patient data is protected at all stages of data collection, transmission and storage.

Chapter 4: Proposed Design -

4.1 Conceptual Design (Architectural) -



1. User Interaction Layer (Frontend/UI)

Components:

UX Panel: Collects user information, medical devices, and placement details.

Text-to-Image Generation Model: Generates a visual of the user wearing medical devices

Registration API: Registers the user and their devices.

Technologies: Streamlit for the UX panel, integrated with a text-to-image generation API.

2. Data Ingestion Layer

Components:

Device Data Receiver: APIs to receive real-time data from medical devices (e.g., wearables like smartwatches, oura rings, insulin pumps).

EHR (Electronic Health Record) Integration: Pull real-time EHR data from the devices once registered.

Data Processing & Normalization: Prepares the data for further analysis and storage.

Technologies: WebSockets for real-time data ingestion, REST APIs for integration with EHR systems.

3. Backend & Processing Layer

Components:

Data Storage: Database for storing user details, device configurations, and real-time data streams.

Analytics Engine: Real-time data processing to generate insights, alerts, and recommendations.

Machine Learning (ML) Engine: Responsible for generating intelligent recommendations and emergency notifications based on the EHR data (using ML models trained on medical datasets).

Technologies:

Backend: Node.js, Python, or Django for API handling.

Database: NoSQL (MongoDB) for device data and real-time storage, SQL for structured user and EHR data.

ML Framework: TensorFlow or PyTorch for training models to generate alerts/recommendations.

Data Streaming: Kafka for managing real-time data streams.

4. Visualization Layer (Unity Digital Twin)

Components:

Unity Model: 3D human model that reflects real-time user data (e.g., heart rate, oxygen level, etc.) using a digital twin representation.

Real-Time Data Display: As the data changes (e.g., heart rate, oxygen level), the digital twin should update dynamically in Unity (e.g., changes in color, animation to indicate stress).

Alerts and Recommendations Display: Visual feedback in Unity, alert popups, and emergency notifications if critical thresholds are met.

Technologies: Unity3D with integration to backend API for real-time updates, Unity WebGL for a browser-based experience (if needed).

5. Alerts, Notifications & Recommendations

Components:

Notification Engine: Monitors key health metrics and triggers alerts when certain thresholds are crossed.

Recommendation System: Uses ML models to provide recommendations based on the user's health data and previous EHR trends.

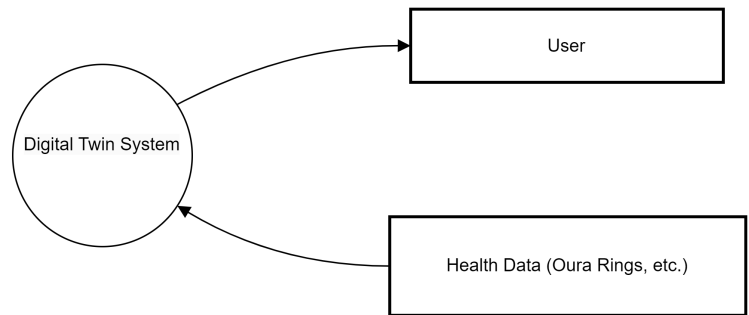
Emergency Response: Sends emergency notifications (e.g., via SMS, email) to both users and medical personnel if necessary.

Technologies: Integration with push notification services (e.g., Firebase Cloud Messaging), email/SMS services (e.g., Twilio), and WebSocket for real-time alerts in the UI.

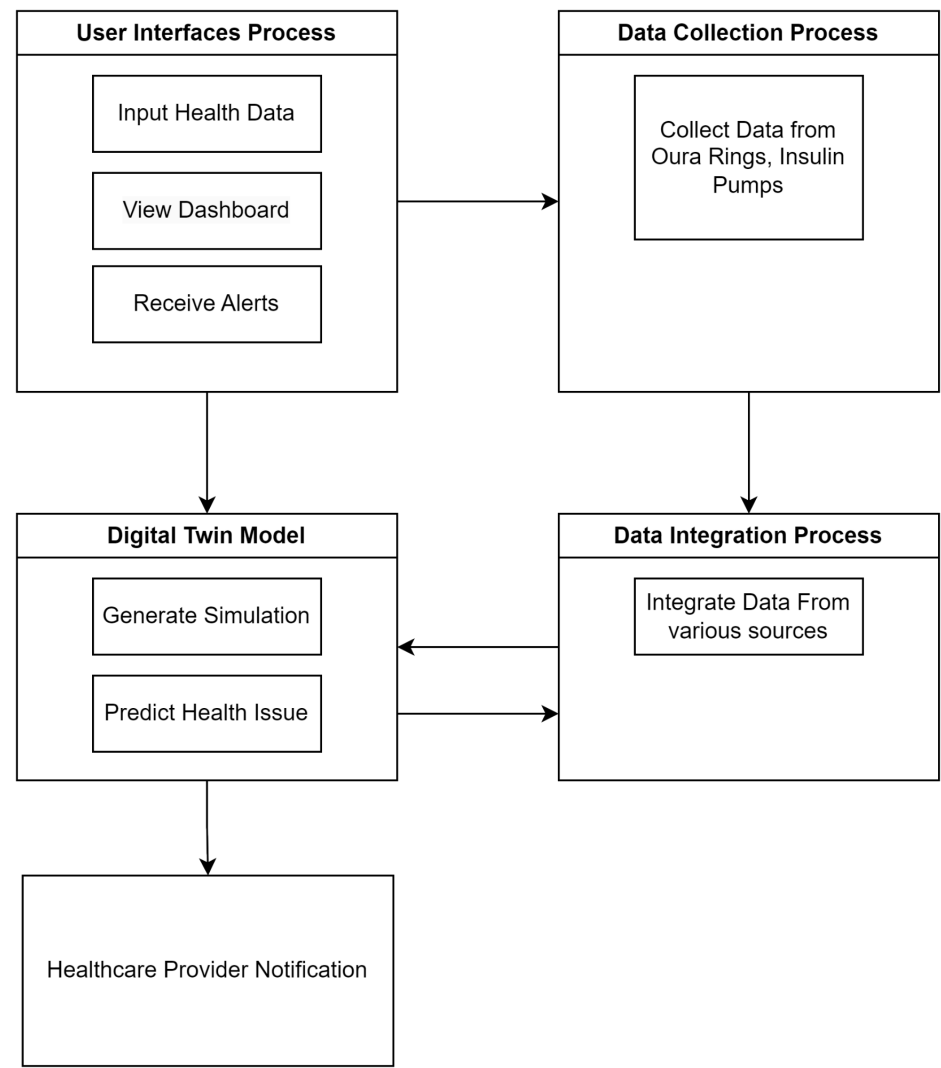
4.2 Design of the proposed system with proper explanation of each :

a. Data Flow Diagram

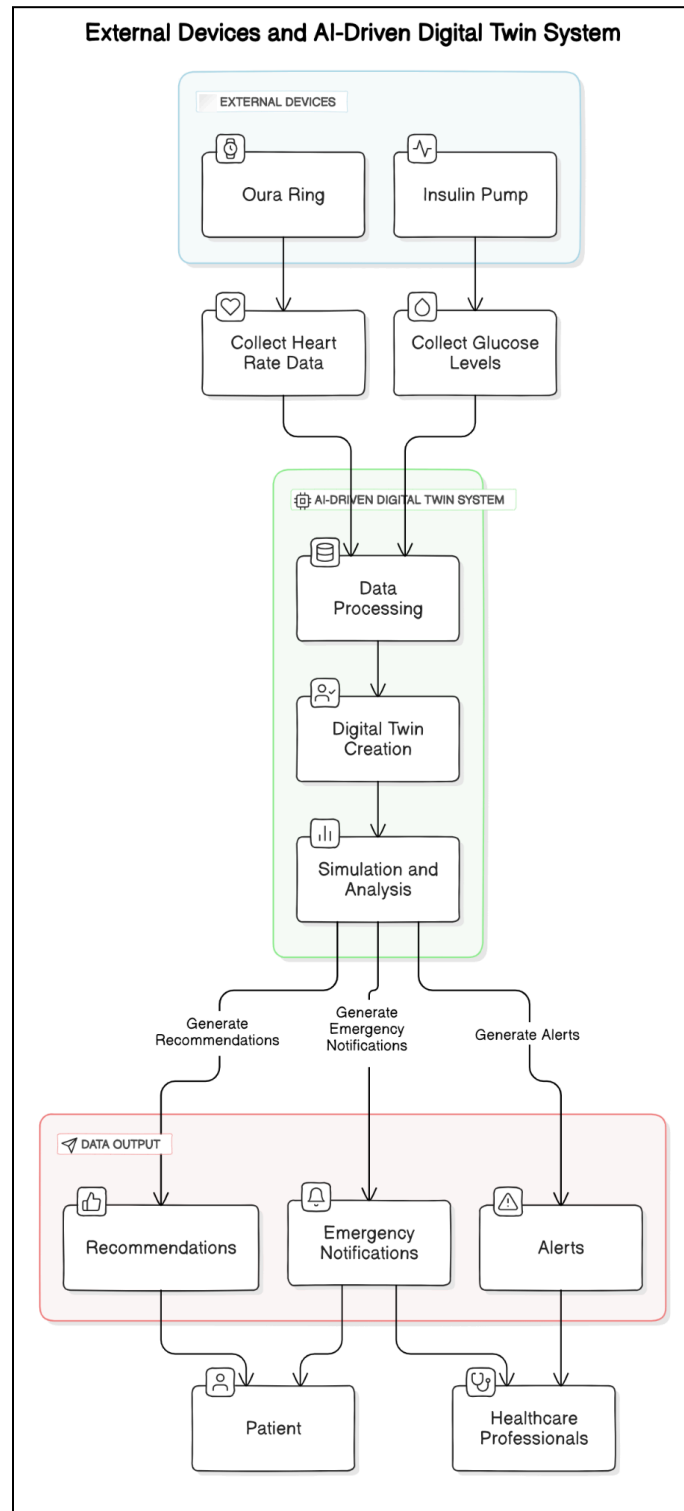
Level 0



Level 1



b.Modular Diagram



Modular Diagram Explanation :

This modular diagram illustrates the process of creating a digital twin system using data from external devices, such as the Oura Ring and an Insulin Pump. Here's a breakdown of the steps:

1. External Devices:

- The Oura Ring collects **heart rate data**.
- The Insulin Pump collects **glucose levels**.

2. AI-Driven Digital Twin System:

- **Data Processing:** The collected data from the external devices is processed.
- **Digital Twin Creation:** A digital twin is created based on this processed data, simulating the patient's physical state.
- **Simulation and Analysis:** The digital twin is then used to run simulations and analyze the patient's health condition.

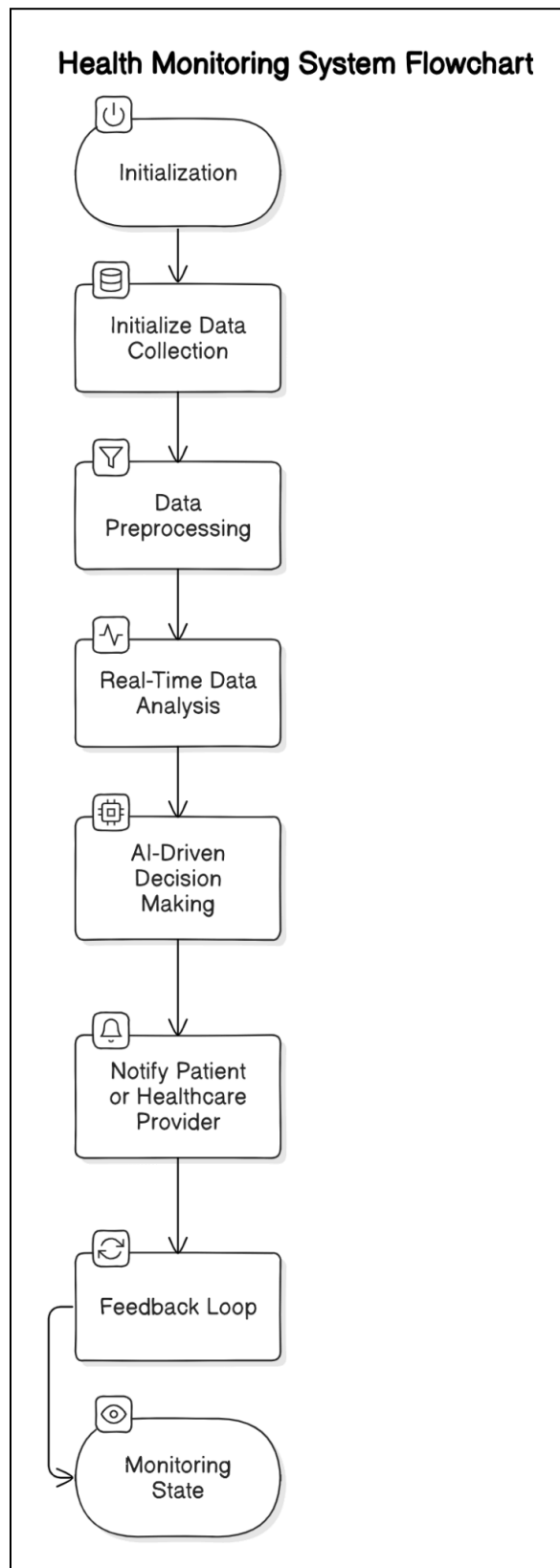
3. Data Output:

- **Recommendations:** Based on the analysis, recommendations are generated for the patient.
- **Emergency Notifications:** If critical conditions are detected, emergency notifications are generated.
- **Alerts:** Alerts are created for healthcare professionals for timely intervention.

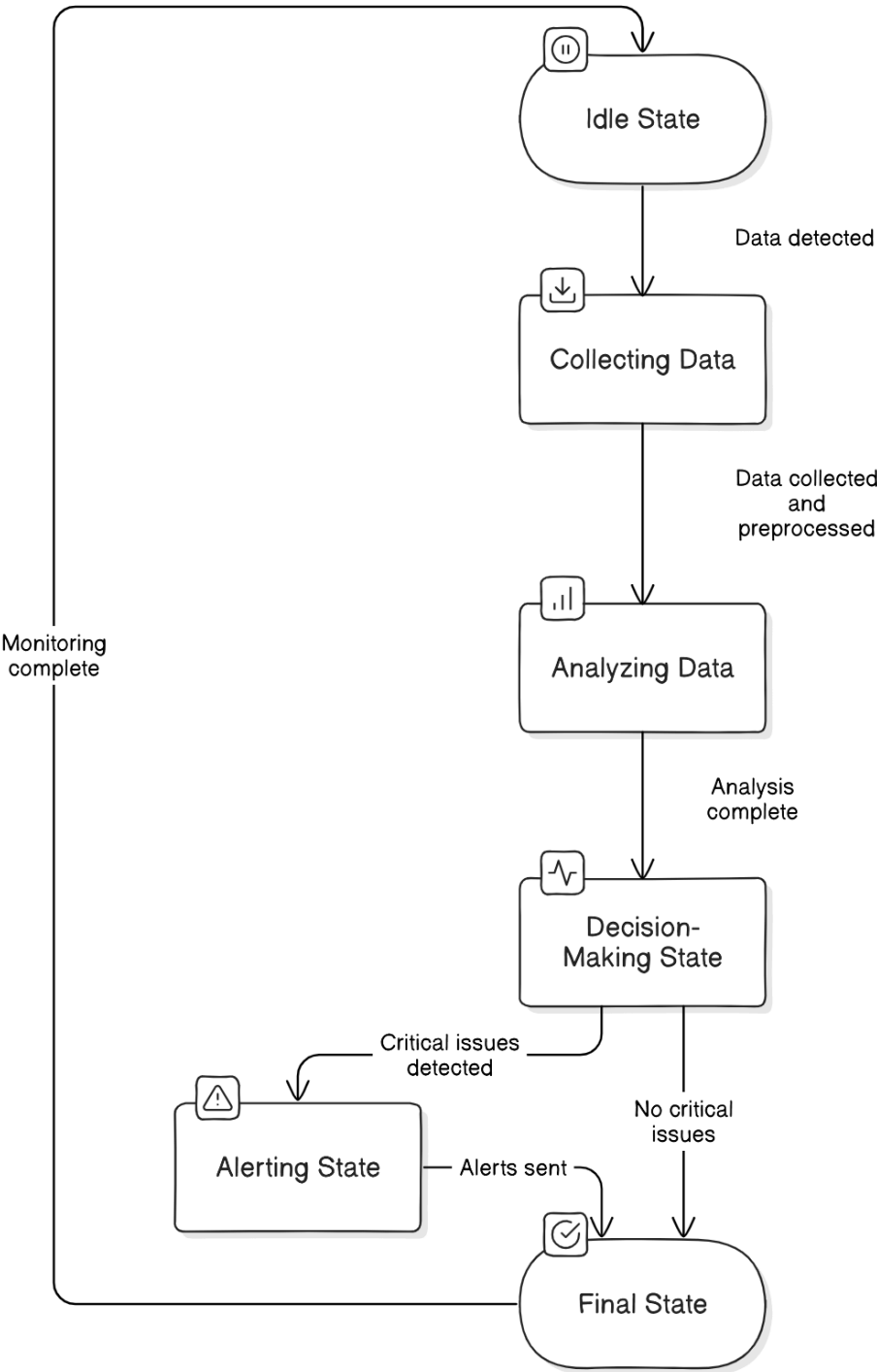
The system supports two key stakeholders:

- The **Patient**, who receives personalized health recommendations.
- **Healthcare Professionals**, who are alerted in case of emergencies or critical health issues.

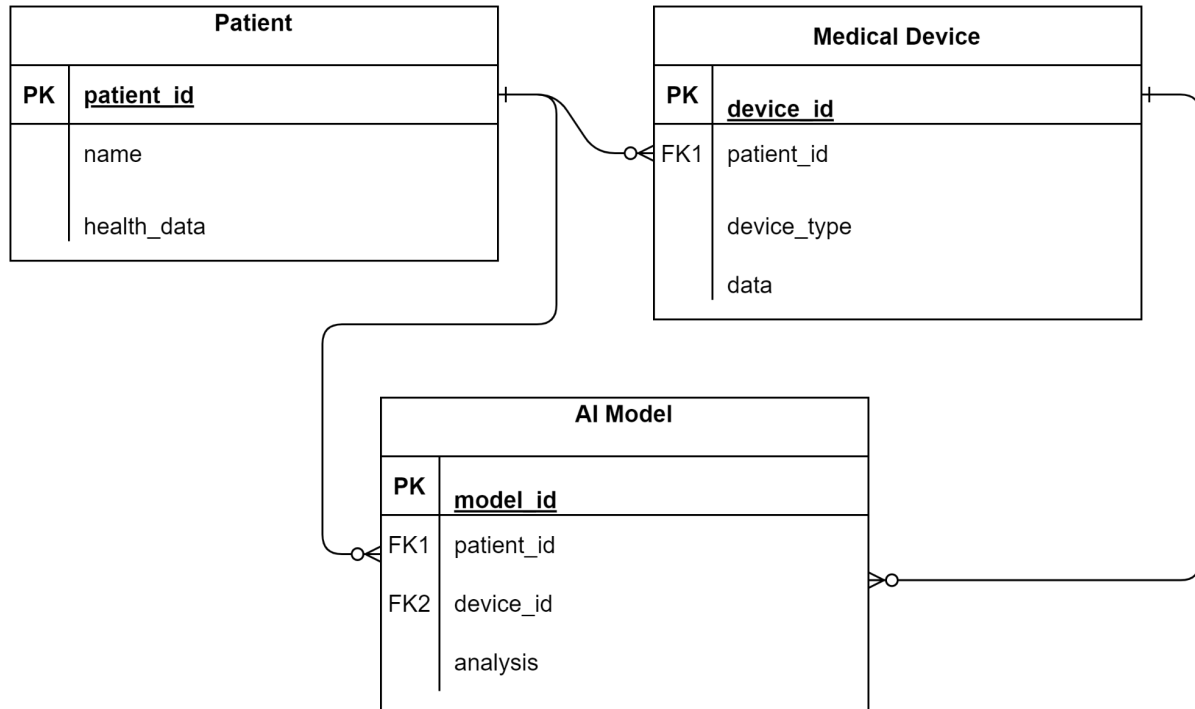
c. Flowchart for the proposed system



d. State Transition Diagram



e. ER Diagram



5. Proposed Results and Discussions

Determination of System Efficiency in the Digital Twin for Medical Solutions:

System efficiency refers to how effectively the digital twin can process real-time data from medical devices (like Oura rings and insulin pumps) to generate outputs, such as health predictions, alerts, or autonomous interventions. Measuring efficiency involves evaluating how the system uses its resources (time, memory, power) to deliver meaningful results (total output). Here's an elaboration on how to approach this:

1. Defining the Key Resources (Input Resources):

- **Time (T):** The time taken by the digital twin system to process real-time data, including receiving, analyzing, and generating insights or actions. This can be measured in milliseconds or seconds, depending on the data flow rate.
- **Memory (M):** The amount of system memory (RAM) used to process and store data from external devices in real time. This includes the memory required for data storage, AI processing, and running simulations of the digital twin.
- **Power (P):** The energy consumption of the system, especially in terms of CPU and GPU usage for computational tasks like AI-driven decision-making, data analysis, and visual rendering in Unity.

2. Total Output (O):

The total output represents the actual results or outcomes produced by the digital twin system. This includes:

- **Predictions:** The AI agent's output, such as predicted blood glucose trends or vital sign changes.
- **Decisions:** Autonomous actions taken by the system, like adjusting insulin levels or alerting healthcare professionals.
- **Simulations and Visualizations:** Real-time simulations and visualizations of the patient's physiological conditions, which are key features of the system.

3. Efficiency Formula:

$$Efficiency = \frac{Total\ Output\ (O)}{Input\ Resources\ (T, M, P)}$$

Where:

- O is the total output, including all predictive analytics, decisions, and simulations.
- T is the time resource (how quickly the system responds).

- M is the memory used to process and store data.
- P is the power consumption for computational tasks.

Accuracy Determination and Monitoring:

Accuracy determination evaluates how precisely the AI agent predicts and responds to real-time health data, such as blood sugar levels or vital signs (e.g., heart rate). The goal is to assess the AI's ability to detect anomalies, such as sudden changes in glucose levels, and make accurate decisions for corrective actions, like adjusting insulin doses. Accuracy is measured by comparing the predicted values with actual outcomes, calculating error rates, and monitoring false positives or false negatives. Continuous accuracy monitoring ensures that the AI agent reliably supports personalized healthcare interventions and reduces potential adverse events.

Performance Evaluation for Autonomous Decision-Making:

Performance evaluation of autonomous decision-making assesses how effectively the AI agent manages medical interventions, such as insulin delivery, based on real-time patient data. This involves measuring the agent's ability to analyze vital signs or glucose levels, predict anomalies, and make timely corrective actions without human intervention.

Key metrics include decision accuracy, response time, and success rate in preventing adverse events. Evaluating the AI's performance ensures it can adjust medical interventions reliably, improving patient outcomes by providing accurate, proactive care. Additionally, this assessment highlights areas for improving the system's responsiveness, precision, and adaptability to varying patient conditions.

6. Plan of action for the next semester

1. Integrating Digital Twin with Oura Rings, Insulin Pumps, etc.

Collaborate with manufacturers of wearables, such as Oura Rings and insulin pumps, to establish secure APIs for seamless data integration. This will enable continuous acquisition of real-time health metrics, creating a comprehensive virtual representation of the user's health. The integration enhances user engagement by allowing individuals to visualize their health data within the Digital Twin, facilitating proactive monitoring and timely interventions.

2. Updating the Dashboard for User-Specific Tracking

Redesign the dashboard interface to provide personalized health insights and alerts tailored to individual user needs. By incorporating user preferences and health goals, the dashboard will feature customizable widgets and visual data representations. This will empower users to track their health trends effectively, recognize patterns, and make informed decisions about lifestyle changes and medical consultations.

3. Integration with Real-Time Streaming Data using Apache Kafka

Implement Apache Kafka for efficient real-time data streaming, ensuring the Digital Twin is continuously updated with the latest health metrics. This scalable and fault-tolerant solution enhances system responsiveness, allowing for instant notifications about significant health changes. Timely alerts enable proactive management of chronic conditions, ensuring users can address potential issues before they escalate.

4. Increasing the Efficiency of Image Generation Model

Optimize the image generation model using advanced machine learning techniques like Generative Adversarial Networks (GANs). This enhancement will improve the quality of visualizations representing user health data and predictive scenarios. By providing detailed visual insights, the system aids healthcare providers in clinical decision-making and allows users to visualize potential outcomes based on treatment options.

7. Conclusions

The project titled "Visual Digital Twin of Medical Solutions for a Specialized Gen AI Agentic Model" represents a significant advancement in healthcare technology. By integrating real-time data from external medical devices such as Oura rings and insulin pumps, the system creates a digital twin that mirrors a patient's health status. This virtual replica, powered by a Gen AI agentic model, enables real-time monitoring, predictive analysis, and autonomous decision-making, which could transform the way healthcare is delivered.

The use of digital twins in healthcare has the potential to enhance patient care by providing more personalized, accurate, and timely insights into health conditions. The autonomous nature of the Gen AI agent allows the system to not only analyze data but also learn from it, adapt to changing scenarios, and make decisions that benefit both patients and healthcare providers. Moreover, the system's ability to integrate with existing medical devices and provide real-time feedback presents a valuable tool for chronic disease management, early diagnosis, and overall healthcare efficiency.

However, challenges such as data privacy, regulatory constraints, and the need for reliable and secure device integration must be addressed to fully realize the potential of this technology. Despite these challenges, the implementation of a digital twin in healthcare presents a groundbreaking opportunity to improve patient outcomes, reduce costs, and streamline medical interventions.

In conclusion, this project stands at the forefront of healthcare innovation, merging artificial intelligence with real-world medical data to create a solution that enhances decision-making, facilitates personalized care, and fosters a more proactive approach to healthcare management. As the system evolves, its impact on the healthcare industry will likely be profound, offering safer, more reliable, and efficient healthcare solutions.

8. References

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9. Review Sheets

Review Sheet -1

12

Class: D17

Project Evaluation Sheet 2024-25

Industry/Inhouse:

Title of Project(Group no): 12 - Development of a Digital Twin for Advanced Cardiovascular Disease

Group Members: ~~Kingla Ahuja (D17C 01), Tahtique Ansari (D17C 04), Devangana Barua (D17C 06)~~
Dipanshu Ghosh (D17C 18)

	Engineering Concepts & Knowledge	Interpretation of Problem & Analysis	Design / Prototype	Interpretation of Data & Dataset	Modern Tool Usage	Social Benefit, Safety Consideration	Environ ment Friendly	Ethics	Team work	Presentati on Skills	Applied Engg & Mgmt principles	Life - long learning	Profess ional Skills	Innov ative Appr oach	Total Marks
Review of Project Stage 1	04	04	04	02	04	02	02	02	02	02	02	02	04	04	48
Comments:															

Signature

Name & Signature Reviewer1

	Engineering Concepts & Knowledge	Interpretation of Problem & Analysis	Design / Prototype	Interpretation of Data & Dataset	Modern Tool Usage	Social Benefit, Safety Consideration	Environ ment Friendly	Ethics	Team work	Presentati on Skills	Applied Engg & Mgmt principles	Life - long learning	Profess ional Skills	Innov ative Appr oach	Total Marks
Review of Project Stage 1	04	05	05	02	04	02	02	02	02	02	02	02	04	04	48
Comments:															

Signature

Name & Signature Reviewer2

Date: 23rd August, 2024

Keep up with the research & good work.

Industry/Inhouse: Group 12

Project Evaluation Sheet 2024-25

Class: DI7

Title of Project(Group no): Development of Digital Twin for Cardiovascular Disease (CVD) Monitoring

Group Members: Kingala Anuja (DI7C 01), Tanishque Ansaari (DI7C 04), Devangana Barua (DI7C 06), Dipanshu (DI7C 18)

	Engineering Concepts & Knowledge	Interpretation of Problem & Analysis	Design / Prototype	Interpretation of Data & Dataset	Modern Tool Usage	Societal Benefit, Safety Consideration	Environment Friendly	Ethics	Team work	Presentation Skills	Applied Engg & Mgmt principles	Life-long learning	Professional Skills	Innovative Approach	Total Marks
Review of Project Stage 1	5	5	5	3	5	2	2	2	2	3	3	3	4	4	46
Comments: Good work done, try to improve quality of image generated.															

Name & Signature

Reviewer1

	Engineering Concepts & Knowledge	Interpretation of Problem & Analysis	Design / Prototype	Interpretation of Data & Dataset	Modern Tool Usage	Societal Benefit, Safety Consideration	Environment Friendly	Ethics	Team work	Presentation Skills	Applied Engg & Mgmt principles	Life-long learning	Professional Skills	Innovative Approach	Total Marks
Review of Project Stage 1	5	5	5	3	5	2	2	2	2	3	3	3	4	4	46
Comments: To validate the work with Myraa & start w/15 next task															

Name & Signature

Reviewer2

Date: 26th September, 2024