A Proposed Framework for Integrating Digital Triage with 3D Human Model for Intuitive Health Visualization and Monitoring

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Abstract: This paper presents a novel integration of digital triage protocols with three-dimensional human digital twin models to enhance patient assessment and clinical decision-making in healthcare. We investigate how Electronic Health Record (EHR) data can be transformed into intuitive, anatomically-relevant visualizations that map health parameters to specific body regions using color-coded indicators. Building upon the B-logic framework from Portable Health Clinic systems, our approach creates personalized 3D patient models that dynamically represent health status through targeted visual cues—from BMI and vital signs to biomarkers and lifestyle factors. The system architecture incorporates anthropometric data and facial recognition to generate individualized avatars, while large language models provide contextual healthcare suggestions based on detected risk factors. This integration addresses limitations in current EHR-based triage systems, particularly regarding alert effectiveness and protocol compliance. While the system shows potential for enhanced visualization, practical implementation may face challenges in data availability, privacy, and clinical validation. The proposed visualization methodology offers healthcare providers and patients an intuitive interface for health monitoring, potentially improving engagement, comprehension, and clinical workflow in both emergency and routine healthcare settings.

1 INTRODUCTION

Over the past decade, the adoption of Electronic Health Record (EHR) systems has transformed modern healthcare delivery. As of 2021, 96% of non-federal acute care hospitals in the United States had implemented certified EHR systems, compared to only 7.6% in 2008 (Office of the National Coordinator for Health Information Technology (ONC), 2021; Jiang et al., 2023). A global survey by the Organisation for Economic Co-operation and Development (OECD) across 27 countries revealed that only 15 had achieved nationally unified EHR systems, underscoring persistent challenges related to interoperability and fragmentation (Slawomirski et al., 2023).

While developed nations are progressively integrating EHR and Electronic Medical Record (EMR) systems, adoption rates in developing countries remain low, ranging from 5% to 30%, primarily due to limited infrastructure, financial constraints, and the lack of standardized health data frameworks (Derecho et al., 2024). One key advancement enabled by EHR systems is digital triage—automated protocols that prioritize patient care based on clinical urgency. However, traditional EHR-based alert systems often suffer from poor protocol compliance, alert fatigue, and suboptimal visualization interfaces. For instance, a randomized controlled study showed no significant

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Table 1: Triage System Categories in Healthcare.

Triage Category	Implementation Context	Representative Systems	Key Characteristics
Emergency Department Triage	Emergency Departments, Pre-Hospital	ESI(Emergency Severity Index), CTAS(Canadian Triage and Acuity Scale), MTS(Manchester Triage System), ATS(Australasian Triage Scale)	Traditional, rule-based methods that help prioritize who gets care first.
AI Driven	EHR Integration, Telehealth, AI-Supported Platforms	HopScore, SERT(System for Emergency Risk Triage), TriageGO	Uses AI and machine learning to predict risk and suggest actions.
Disaster & Mass Casualty	Emergency Situations, Pandemic Response	START(Simple Triage and Rapid Treatment), JumpSTART, Triage Sieve, SAVE	Helps in chaotic events by categorizing patients.
Specialized	Pediatric, Mental Health	JumpSTART, MHTS (Mental Health Triage Scale)	Tailored for specific populations like children or people with mental health needs.

improvement in triage compliance through passive EHR alerts, highlighting the need for more intuitive and dynamic triage strategies (Holmes et al., 2015).

This paper proposes a framework integrating digital triage protocols with three-dimensional human digital twin (HDT) models. By leveraging anthropometric data, facial recognition, and color-coded visualizations, the system aims to transform structured EHR data into an anatomically meaningful 3D representation. This approach enables healthcare providers and patients to monitor and understand health risks more intuitively.

Research Question: How to integrate and visualize medical triage with a 3D human model?

To address this question, the paper introduces a framework that links B-Logic-based triage from Portable Health Clinic (PHC) systems with AI-generated digital avatars. The system also incorporates large language models (LLMs) to provide personalized health suggestions based on mapped risk factors. The proposed methodology targets both emergency and routine care, particularly in low-resource settings, offering a potential pathway toward more accessible and personalized healthcare monitoring.

2 AVAILABLE TRIAGE SYSTEM AND ITS LIMITATION

In an EHR-integrated triage workflow, clinicians (often triage nurses) enter a patient's initial information—vital signs, symptoms, and chief complaint—directly into a module of the EHR. This digital form captures key data points and often enforces required fields to ensure completeness (Aronsky et al., 2008).

The integration of triage systems within Electronic Health Record (EHR) platforms represents a significant advancement in healthcare informatics and clinical decision support. Multiple triage frameworks now operate within these digital environments and can be categorized into four primary classifications based on implementation context and clinical focus.

Emergency Department Triage systems, such as the widely adopted Emergency Severity Index (ESI) (Aronsky et al., 2008; Liu et al., 2022) and Canadian Triage and Acuity Scale (CTAS) (Office of the National Coordinator for Health Information Technology (ONC), 2021), Australasian Triage Scale(ATS) (Ebrahimi et al., 2015) , Manchester Triage System (MTS) (Azeredo et al., 2015) offer structured protocols used in emergency and urgent care settings to prioritize treatment based on patient acuity and resource requirements.

Mass Casualty Incident (MCI) Triage protocols are specifically designed for disaster scenarios and large-scale emergencies. Systems such as Simple Triage and Rapid Treatment (START), JumpSTART (for pediatric patients), and the Triage Sieve categorize patients using a color-coded classification (immediate/red, delayed/yellow, minor/green, and expectant/black) to optimize resource allocation (Bazyar et al., 2019; Wang et al., 2022).

Technology-Assisted Triage includes informatics-driven systems like HopScore (Levin et al., 2018), the SERT (System for Emergency Risk Triage), and TriageGO (Johns Hopkins Medicine, 2022), which utilize artificial intelligence and EHR integration to predict clinical risk and suggest appropriate care pathways in real time.

Specialty Population Triage frameworks are designed for specific groups such as pediatric or men-

Table 2: B-logic triage system.

Parameter	Lower Warning	Green	Yellow	Orange	Red	Upper Warning
Height (cm)	<100.0					>200.0
Weight (kg)	<25					>100.0
BMI		<25	≥25 & <30	≥30 & ≤35	>35	
Waist (cm) Male	<40.0	<90.0	≥90.0	NA	NA	>120.0
Waist (cm) Female	<40.0	<80.0	≥80.0	NA	NA	>110.0
Hip (cm)	<40.0					>120.0
Waist Hip Ratio Male		<0.90	≥0.90	NA	NA	-
Waist Hip Ratio Female		<0.85	≥0.85	NA	NA	-
Temperature (C)	<33.0	≥37.0 & <37.5	≥37.5	NA	NA	>39.0
HBsAg		negative			positive	
Smoking					positive	
Urine Sugar		-	+-	Others		
Urine Protin		-	+-	Others		
Urinary Urobilinogen	+-			Others		
Oxygenation of Blood (%)	>100	≥96	≥93 & ≤96	≥90 & <93	<90	<92
Blood Pressure Systolic	<70	<130	≥130 & <140	≥140 & <180	≥180	>220
Blood Pressure Diastolic	<50	≤85	≥85 & <90	≥90 & <110	≥110	>140
Blood Sugar (mmol/dl) PBS	<3.0	<7.78	≥7.78 & <11.11	≥11.11 & <16.67	≥16.67	>30.0
Blood Sugar (mmol/dl) FBS	<3.0	<5.56	≥5.56 & <7.0	≥7.0 & <11.11	≥11.11	>20.0
Blood Hemoglobin (g/dl)	>18.0	≥12.0	≥10.0 & <12.0	≥8.0 & <10.0	<8.0	<6.0
Pulse Rate (beats/min)	<50	≥60 & <100	≥50 & <60	<50 OR ≥120		>130
Arrhythmia		Normal			Others	
Blood Cholesterol (mg/dl)	<120.0	≤200.0	>200.0 & ≤225.0	≥225.0 & <240.0	≥240.0	>300.0
Blood Uric Acid (mg/dl) Male	<2.5	≥3.5 & ≤7.0		>7.0 & ≤8.0	≥8.0	>12.0
Blood Uric Acid (mg/dl) Female	<2.5	≥2.4 & ≤6.0		>6.0 & ≤7.0	≥7.0	>12.0

tal health patients. These include systems like Jump-START (Bazyar et al., 2019; Wang et al., 2022) and the Mental Health Triage Scale (MHTS) (Broadbent et al., 2007), which tailor triage protocols to the unique needs of their respective populations.

The triage systems perform effectively within their domains, offering structured support for clinical decision-making. However, they face limitations in patient engagement due to health literacy gaps. Many patients struggle to interpret medical data and triage outcomes presented in standard EHR interfaces. Moreover, the lack of intuitive, body-mapped visualizations reduces clarity and makes it harder for users to understand their health status. These issues highlight the need for more accessible and patient-friendly triage solutions.

3 PORTABLE HEALTH CLINIC AND B-LOGIC

The Portable Health Clinic (PHC), developed by Kyushu University and Grameen Communications, delivers telehealth services to underserved rural areas using a portable briefcase with diagnostic tools. Health data is sent to a remote call center, where doctors review EHRs and provide consultations via telemedicine. A color-coded triage system (green to red) guides patient prioritization. Integrated with the PHC, the B-Logic framework uses predefined medical parameters to classify patients by risk level, enabling efficient diagnosis and resource allocation (Ahmed et al., 2013). table 2 shows the B-logic triage system.

4 CONCEPT OF 3D VISUALIZATION OF PHC TRIAGE SYSTEM

The PHC system collects patient data and stores it in a database, automatically assigning each patient to a color-coded triage category. The new proposed system will generate a 'patient digital twin' and use these data to provide customized suggestions and visualizations, allowing individuals to view and understand their health status through a personalized digital representation. In fig. 1, it shows the system architecture of the proposed system.

4.1 Digital Twin with Real-Time Triage

To make the digital twin with a real-time triage system, we need to break it down into two parts.

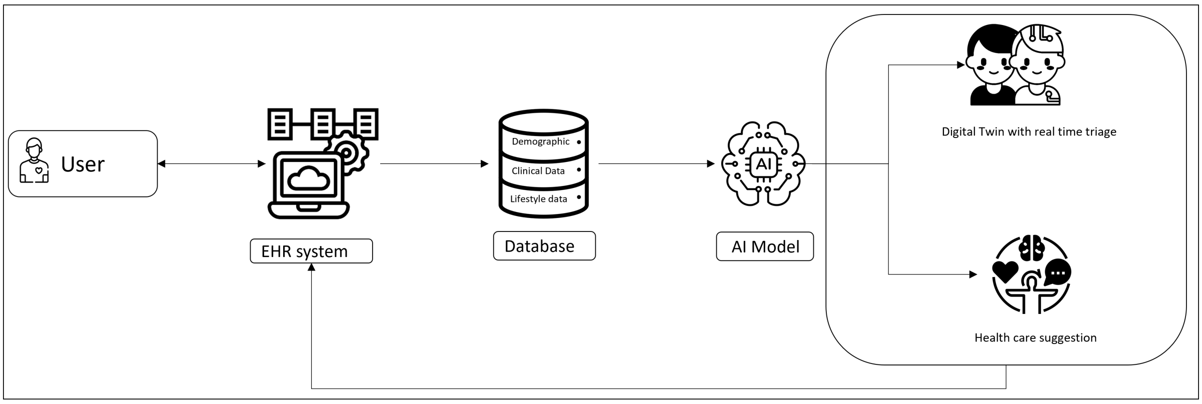

Figure 1: Proposed framework.

4.1.1 Silhouette Estimation from Anthropometric Data

Almost every EHR system collects the anthropometric data of a patient, such as height, weight, etc. Also, PHC has the patient's anthropometric data. We will use the data to generate a specific silhouette of the patient. In fig. 2, it shows how the anthropometric data will be the input of an AI model that will make the silhouette of the patient.

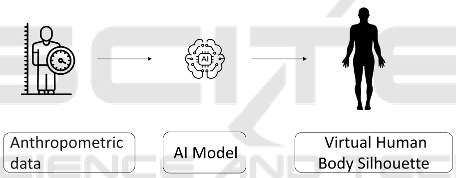

Figure 2: Anthropometric data to silhouette structure.

4.1.2 3D Face Construction from Image Data

EHR systems have patient images in their database. As fig. 3 suggests, the AI model will create a 3D face based on the image, and the face will merge with the human silhouette to make a clone of the individual patient.

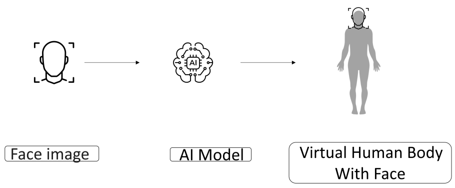

Figure 3: User image to 3D face structure.

4.2 Mapping Health Parameters to Body Parts

The system will map each key health parameter to a specific body region on the 3D model, indicating where the effect of that metric is most visible or relevant. Here's a breakdown of the parameters and how to visualize them on the body

4.2.1 Height, Weight, BMI (Body Mass Index)

These relate to the overall body. A common approach is to reflect BMI by the overall silhouette. For instance, the entire figure could be outlined or filled with a color representing whether the BMI is normal or high. A green full-body glow for normal BMI, vs. orange or red if BMI is in overweight/obese range, immediately signals the category.

4.2.2 Waist, Hip Measurements, and Waist-Hip Ratio

To emphasize the abdominal and hip region, a colored band can be drawn around the waist or hips of the model. For instance, a ring or outline at the waist level may be displayed in green to indicate a healthy circumference, while red can denote measurements beyond the risk threshold. Since the waist-to-hip ratio serves as a single risk indicator, the entire midsection, including the stomach and hip area, can be color-coded to reflect risk levels. A high ratio, indicative of central obesity, may be represented by a red-colored region. This visual mapping enables users to perceive an expanding red belly when waist size becomes a concern. Additionally, a subtle translucent "slice" or disc around the waist can be incorporated to display the numeric value of the ratio. A straightforward approach involves highlighting the torso, particularly the abdominal area, with severity-based color coding for waist and hip metrics.

Table 3: Health Parameters Mapping.

Health Parameter	Mapped Body Region	Visualization Approach
Height, Weight, BMI	Overall body	Color-coded whole body (green/yellow/red for BMI), numeric values for height/weight
Waist, Hip Measurements	Abdomen and hip region	Colored band around waist/hips, midsection highlighted based on risk
Body Temperature	Forehead, head, whole body	Heatmap overlay (blue to red gradient), forehead glow
Blood Pressure	Arms, chest	highlighted arms for BP, heart icon on chest for pulse
Blood Oxygenation (SpO_2)	Fingertips, lungs/chest	Glowing fingertip (green/yellow/red), lung overlay in color
Blood Sugar (Glucose)	Fingertip, hands, veins	Hand highlight, blood droplet icon, color-coded veins
Hemoglobin (Hb)	Circulatory system	Blood vessels colored red (normal) or blue (anemic), pale skin tone
Cholesterol	Heart/chest	Heart turns color for cholesterol risk, artery clog icons
Uric Acid	Joints (feet, knees)	Foot/knee highlights for uric acid buildup
Smoking	Lungs, mouth	Lungs overlaid with smoky texture or colored (yellow/red)
Urine Parameters	Kidneys, bladder	Kidneys and bladder highlighted, color-coded for risk

4.2.3 Body Temperature

Body temperature is commonly measured at the forehead or ear, but fever affects the entire body. An effective method for visual representation is a heatmap overlay that spans the entire body. This can be implemented using a gradient shader, where cooler temperatures are represented in blue and elevated temperatures in red. Given that the normal human body temperature is approximately 37°C, a simplified approach could involve using green to denote normal temperature ranges and red to indicate fever. To enhance clarity, specific regions, such as the forehead, can be emphasized using a thermometer icon or a red glow, aligning with the common practice of forehead-based temperature checks. Alternatively, the model's facial or forehead region can dynamically change color—retaining a normal skin tone when within the healthy range and turning flushed red when fever is detected. If a full-body heatmap is employed, care should be taken to ensure it does not interfere with other visual overlays. In such cases, a subtle overall tint adjustment—such as a slight red hue when fever is present—can effectively signal an elevated temperature. Given that body temperature is represented as a single numerical value, a minimalistic approach, such as a small colored indicator (e.g., a red dot on the forehead), may also suffice while maintaining an intuitive and informative visualization.

4.2.4 Blood Pressure and Pulse Rate

Blood pressure and pulse rate are critical indicators of circulatory health, typically measured on the arm and closely associated with cardiovascular function. To effectively visualize these vitals, a model can highlight specific anatomical regions where measurements commonly occur. For instance, the upper arm or wrist—locations used for blood pressure monitoring—can be color-coded to indicate status, with green representing normal levels and red signaling hypertension. Additionally, an icon of a heart or artery can be placed on the arm to reinforce the association with circulatory health. For pulse rate visualization, an intuitive approach is to use a heart symbol on the chest that dynamically animates to mimic a beating heart. This icon could change color to reflect pulse rate abnormalities—red for tachycardia (elevated heart rate) and blue for bradycardia (low heart rate). Some avatar-based monitoring systems already implement similar features, where heart icons adjust color based on real-time vital signs. Since blood pressure and pulse rate are interrelated, a dual representation could enhance clarity: the heart symbol on the chest can reflect pulse rate through animation and color changes, while the arm region can indicate blood pressure status. In cases of severe hypertension, an extended visualization—such as highlighting the blood vessel network in red—can effectively convey cardiovascular strain. Conversely, hypotension or a dangerously low pulse could be depicted using a blue tint or a slow pulsating animation. For user interaction, a clickable interface where selecting the arm or heart symbol provides precise numerical readings of blood pressure and pulse rate would enhance usability. However, even without interaction, a color-coded system ensures immediate recognition of circulatory health status at a glance

4.2.5 Blood Oxygenation (SpO_2)

Blood oxygen saturation (SpO_2) is a vital parameter typically measured at the fingertip using a pulse oximeter or inferred from lung function. In a digital twin, it can be visualized by highlighting the fingertip or lungs. A color-coded glow—green (normal), yellow (moderate), red (low)—can indicate oxygen levels, with pulsing effects enhancing visibility. For anatomical context, the lungs may be tinted red to signal respiratory distress. Combining fingertip and lung highlights offers intuitive feedback. Interactive elements, like clicking for exact values, can further improve user engagement and health monitoring clarity.

4.2.6 Blood Sugar (Glucose)

Blood glucose levels are typically monitored through finger-prick tests or continuous glucose monitors (CGMs) placed on the arm. While glucose metabolism affects the entire body, an effective visual representation should focus on intuitive indicators, such as the hands (where blood tests occur) or a blood droplet symbol to signify sugar levels. A simple and clear method is to highlight the fingertip, where traditional glucose tests are performed. A small droplet icon can be placed on the fingertip, changing color to reflect blood sugar status: Green for normal glucose levels Yellow for moderate elevation Red for high blood sugar (hyperglycemia) For a more anatomical approach, a vein or artery overlay could be used to signify blood sugar levels, though this is a more abstract representation. If the model includes visible veins, they could subtly change color based on glucose concentration. However, to maintain clarity and usability, a color-coded highlight on the hands is a more direct and intuitive approach. User interaction can be enhanced by allowing the glowing hand to be clickable, displaying real-time blood sugar readings. In some medical visualization systems, high blood sugar is represented across multiple organs due to its long-term effects on areas such as the kidneys, eyes, and nerves, but this level of detail may be unnecessary for general use. If an anatomical focus is preferred, the pancreas (responsible for insulin production) could be highlighted, though most lay users may not immediately recognize its location. Alternatively, a small glucose meter icon placed near the model could provide additional clarity. However, following the established visual scheme, a color-coded hand region remains the most intuitive and immediately recognizable indicator of blood sugar status.

4.2.7 Hemoglobin

Hemoglobin (Hb) plays a crucial role in the blood's oxygen-carrying capacity, directly influencing circulation and tissue oxygenation. A decrease in hemoglobin levels, indicative of anemia, may be represented through visual changes in the circulatory system. For instance, if a model includes arteries and veins, normal hemoglobin levels could be depicted with bright red vessels, while anemia might be illustrated using a dull blue or gray hue. In the absence of detailed vascular representation, an alternative approach could involve using a blood drop icon over the torso or adjusting the overall skin tone—rosy for normal hemoglobin and pale or bluish for low levels. Given hemoglobin's impact on energy and oxygenation, visual cues such as highlighting the chest (symbolizing the heart and circulation) or the arm veins (where blood is commonly drawn for testing) may enhance interpretability. Maintaining consistency with oxygen-related indicators, such as linking hemoglobin visualization to the chest or arterial pathways, can further reinforce its physiological significance.

4.2.8 Cholesterol

Cholesterol and uric acid are distinct physiological markers, each associated with specific body systems. Cholesterol is primarily linked to cardiovascular health, while uric acid is connected to joint function, particularly in conditions like gout. To visualize cholesterol levels, the heart or arterial system can serve as a focal point, with color-coded indicators—such as a red or orange hue—to signify elevated cholesterol and potential cardiovascular risk. Additional elements, such as an artery-clogging icon, could further reinforce this association. For uric acid, visualization can be centered on the joints, with a focus on areas most commonly affected by gout, such as the big toe, knees, or hands. A practical approach would be to highlight the foot or toe joint when uric acid levels are high, as gout frequently manifests in these areas first. Alternatively, a generic joint icon, such as a knee, could be used to represent broader joint-related risks. If highlighting multiple joints becomes complex, selecting a single representative joint—such as the knee or foot—provides clarity while maintaining effectiveness. A user-interactive model could allow access to specific details by clicking on the heart for cholesterol-related data and the foot or knee for uric acid levels, ensuring intuitive engagement with the health metrics.

4.2.9 Smoking

Smoking significantly affects lung health and increases disease risk. In the 3D model, this can be visualized by highlighting the lungs—healthy lungs appear normal, while smoker's lungs are tinted gray or black. A color gradient (green to red) can indicate smoking intensity. Since it's a lifestyle factor, a simple visual toggle or overlay can signal smoking status, enhancing user awareness of its health impact.

4.2.10 Urine-Related Parameters

Urine-related parameters, such as urine sugar, ketones, and kidney function markers, are closely tied to the renal system, including the kidneys and bladder. A clear visualization of these metrics can be achieved by mapping them to the anatomical locations of these organs. The kidneys, positioned in the lower back, could be highlighted from either the rear view or subtly shown from the front as faint outlines on the sides. The bladder, located in the lower abdomen, can also serve as a visual indicator for urine-related issues. Color-coded cues can effectively communicate abnormal findings. For instance, healthy kidneys and bladder could be depicted in green, while abnormal readings—such as proteinuria or elevated creatinine—could prompt a shift to orange or red. A more simplified approach might use a single urinary tract icon, such as a kidney symbol on the abdomen, to consolidate renal health indicators. However, given the distinct roles of the kidneys and bladder, representing both individually enhances clarity. If the model allows rotation, users could view the kidneys from the back, reinforcing anatomical accuracy. By linking color changes to specific urine test abnormalities, this approach provides an intuitive and direct way to visualize renal function concerns.

4.3 Healthcare Suggestion

The system will incorporate a triage-based approach using a large language model (LLM) to provide personalized healthcare suggestions and motivate patients toward better health management. By analyzing key health parameters, the model will assess risk levels and generate tailored recommendations. For example, if high cholesterol or elevated blood pressure is detected, the system may suggest lifestyle changes such as dietary modifications, increased physical activity, or medical consultation. Beyond medical advice, the system will also focus on patient motivation. Instead of merely presenting risk factors, it will use positive reinforcement and actionable steps to encourage behavior change. If a patient shows early signs of dehydration or kidney strain, the system might prompt hydration reminders and explain the benefits of maintaining optimal fluid balance. Similarly, for smokers, it could offer quitting strategies, highlight immediate health benefits, and suggest resources for smoking cessation. The integration of an LLM allows for a dynamic and engaging interaction, where responses are not only medically relevant but also empathetic and motivating. By adapting to patient needs and health trends, the system can enhance patient engagement, encourage proactive healthcare decisions, and ultimately contribute to improved long-term wellbeing.

5 DISCUSSION

This study presents a concept of integration digital triage system with human digital twin models to improve healthcare visualization and patient monitoring. By mapping clinical parameters to specific body regions on a 3D model, the system offers an intuitive interface that enhances both patient understanding and clinician decision-making. It holds particular promise in underserved areas, supporting remote assessments and low-resource healthcare delivery through the Portable Health Clinic model.

Despite its potential, the system has notable limitations. Accurate avatar generation depends on reliable anthropometric and facial data, which may not always be available, especially in rural or under-resourced settings. The use of facial recognition also raises ethical and privacy concerns, highlighting the need for strict data protection and informed consent.

Additionally, reliance on AI for triage decisions introduces risks, including algorithmic bias and misinterpretation of diverse clinical presentations. These risks are especially relevant in global health contexts where population data may be underrepresented in training datasets.

Future work should include clinical validation, user studies, and the integration of AI methods to ensure fairness and trust. Addressing these challenges is critical for safe, effective, and ethical implementation across diverse healthcare settings.

6 CONCLUSION

This paper has presented a conceptual framework for integrating digital triage protocols with 3D human digital twin models to enhance healthcare visualization, patient monitoring, and decision-making. The proposed system leverages anthropometric data and facial recognition to create personalized 3D models that visually represent health parameters in anatomically relevant locations. By implementing a color-coded visualization scheme based on the B-logic triage framework, the system enables intuitive interpretation of complex health data. The incorporation of LLM-based healthcare suggestions further enhances the system's utility by providing personalized recommendations and motivational prompts based on detected risk factors. This combination of visual representation and actionable guidance represents a significant step toward more patient-centered healthcare monitoring. The technology has particular promise for remote healthcare delivery in underserved communities, building upon the Portable Health Clinic model. While technical challenges remain in implementation and integration with existing EHR systems, the approach offers a promising path to improve patient engagement, enhance clinical decision-making, and ultimately advance healthcare delivery through more intuitive and accessible health information visualization.

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