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Design and Development of an Intelligent Web-Based Digital Human for Emotionally Aware Human–Computer Interaction

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Abstract: *The development of digital humans has become an important area of interest in artificial intelligence and human-computer interaction, aiming to create virtual entities that can simulate human communication, expressions, and intelligence in real time. This project, titled "Development of Digital Humans," is centered on developing an intelligent, interactive system that engages users in human-like dialogue through web-based platforms. Unlike conventional chatbots or voice assistants, the proposed digital human integrates emotion modeling, memory retention, and contextual understanding to enhance the realism and responsiveness of interaction. The system is built using PHP, JavaScript, HTML, CSS, and SQL, and features a modular design architecture that incorporates natural language processing, real-time feedback mechanisms, and a lightweight database structure. This ensures compatibility with a wide range of devices, especially in low-resource environments. One of the core innovations is the inclusion of persistent memory, which allows the digital human to recall user-specific data over multiple sessions enabling personalized and continuous engagement. A mixed-method research approach was adopted, involving user surveys, expert interviews, and comparative analysis of existing platforms such as Apple Siri, Amazon Alexa, Google Assistant, and Samsung NEON. The study identified limitations in current systems, including lack of adaptability to local languages, minimal emotional intelligence, and high bandwidth demands. These findings shaped the design and implementation of the proposed system. Results from system testing revealed improved user satisfaction, reduced latency, and enhanced personalization features. The project offers a scalable framework for deploying digital humans in diverse sectors including virtual learning, online therapy, customer engagement, and digital companionship. It also lays the foundation for future research in ethical AI, multilingual communication, and intelligent virtual presence, contributing to a more human-centered digital future.*

Keywords: *Digital Human, Natural Language Processing, speech synthesis, 3D animation*

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1.0 Introduction

Technological advancements over the past decade have significantly reshaped human-computer interaction. With rapid progress in artificial intelligence (AI) and machine learning (ML), systems that simulate human behavior have become increasingly prevalent. Among these innovations is the *Digital Human*—a virtual entity capable of human-like interaction through speech, facial expressions,

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gestures, and emotional responses. Digital humans enable immersive engagement across domains such as education, healthcare, customer service, and entertainment (Park & Lee, 2022).

Unlike traditional interfaces that rely on static visuals or simple chatbots, digital humans employ multimodal communication. Using natural language processing (NLP) for understanding user input, facial animation for emotional expression, and real-time response generation, they facilitate intuitive and emotionally aware interaction (Wang et al., 2020). The growing demand for scalable and human-like virtual assistants has fueled development in this field, as organizations seek intelligent systems capable of delivering personalized, empathetic, and context-aware services. Examples include digital tutors for online learning and virtual healthcare companions that assist patients remotely (Zhou et al., 2019).

For computer science undergraduates, developing a digital human provides an opportunity to integrate theoretical and practical knowledge in software engineering, AI, UX design, and web technologies. Such a system typically combines HTML, CSS, and JavaScript for front-end interaction; PHP and SQL for backend processing; and AI models for intelligent response handling. This multidisciplinary approach aligns with modern trends in full-stack and intelligent system design.

In developing countries such as Nigeria, adoption of digital human technologies remains limited. Most existing solutions are simple chatbots or voice-based assistants constrained by cost, lack of local expertise, and restricted access to advanced AI tools (Ajayi & Olatunji, 2021). Consequently, the potential of emotionally intelligent and visually interactive systems is yet to be fully realized.

This project therefore focuses on developing a web-based digital human using open-source and accessible technologies. The goal is to simulate realistic, human-like interaction through a visual avatar that interprets input, generates intelligent responses, and engages users naturally. By leveraging affordable tools, the work seeks to promote local innovation in AI-driven interaction systems while contributing to research in human-computer interaction.

The outcome is expected to enhance understanding of interactive digital systems in resource-constrained contexts and provide a template for future development of human-centered AI solutions.

1.1 Aim and Objectives

The aim of this research is to design and implement an intelligent digital human capable of simulating realistic human behavior and communication to enhance user experience in education, healthcare, and customer service.

The objectives are to:

(i) Simulate real-time human interaction through AI-driven behavior and responsive emotional cues.
(ii) Design a user-friendly interface with a relatable human avatar capable of expressions and gestures.
(iii) Integrate speech synthesis and NLP to enable understanding and natural language response.
(iv) Implement backend dialogue management with memory for personalized interactions.
(v) Ensure adaptability across multiple domains such as teaching, reception, and mental health support.
(vi) Evaluate system usability and realism through user testing and feedback.

1.2 Literature review

The evolution of digital humans has been shaped by a convergence of advancements in artificial intelligence (AI), computer graphics, natural language processing (NLP), and human-computer interaction (HCI). Initially conceptualized in the realm of science fiction, digital humans have become a reality in

industries such as entertainment, healthcare, customer service, and education. Early digital human representations were largely limited to static avatars or computer-generated images lacking interactivity or behavioral intelligence. However, as computing power and machine learning capabilities expanded, more sophisticated and lifelike models began to emerge.

Digital humans evolved significantly through the integration of AI-based algorithms, particularly deep learning models that could simulate facial expressions, speech, and gestures in real time. The introduction of Generative Adversarial Networks (GANs) and convolutional neural networks (CNNs) has made it possible to create hyper-realistic human faces and movements, revolutionizing the field (Karras et al., 2019). Moreover, the integration of emotion detection and context-aware systems allowed these digital entities to engage users more naturally and adaptively.

Historically, digital humans have transitioned from non-interactive 3D characters used in gaming and film to highly responsive, AI-powered personas capable of engaging in dynamic conversations. Companies like Soul Machines and UneeQ have pioneered the development of emotionally intelligent digital humans that serve in customer-facing roles across multiple sectors (Williams et al., 2021). These digital entities not only mimic human speech and gestures but also respond empathetically based on real-time sentiment analysis, making them valuable tools in virtual assistance and online therapy.

Importantly, the growth of web-based platforms and the proliferation of cloud computing have further accelerated the development and deployment of digital humans. Unlike traditional applications confined to specific devices, modern digital humans can operate in distributed environments accessible through browsers and mobile apps (Chen et al., 2020). These technological advances have turned digital humans from mere visual constructs into fully interactive and intelligent agents.

The development of digital humans is deeply rooted in the convergence of artificial intelligence (AI), machine learning (ML), and modern web technologies. AI provides the foundational intelligence needed to simulate human cognition and responsiveness, while ML enhances adaptability and personalization. Together, these technologies empower digital humans to understand context, learn from user interactions, and respond in human-like ways (Nguyen & Nguyen, 2021).

Artificial intelligence plays an import role in enabling digital humans to process natural language, recognize emotions, generate responses, and exhibit reasoning abilities. Natural Language Processing (NLP), a branch of Artificial intelligence (AI), allows digital humans to interpret and generate human language with increasing fluency and contextual awareness. Recent innovations in large language models, such as BERT and GPT architectures, have significantly enhanced digital human communication skills (Devlin et al., 2019). These models enable virtual humans to maintain coherent conversations, answer complex queries, and even mimic conversational tones.

Machine learning further elevates the intelligence of digital humans by allowing them to learn from experience. Through reinforcement learning and supervised learning algorithms, digital humans can adapt their behaviors based on feedback and historical data. For example, a customer service digital agent can improve its response accuracy and tone based on prior user interactions, leading to more refined engagement (Sun et al., 2020). Emotion recognition powered by computer vision and sentiment analysis also enables digital humans to modulate their reactions in real time, thereby enhancing user trust and empathy.

Web technologies are equally essential in bringing digital humans to life across

platforms. HTML5, CSS3, JavaScript, and WebGL facilitate the rendering of interactive and visually dynamic digital avatars within browsers. With the support of frameworks like TensorFlow.js and Three.js, developers can integrate AI capabilities and 3D animations directly into web interfaces, ensuring seamless access to digital humans across devices (Zhao et al., 2021). Furthermore, cloud computing and APIs allow for real-time data processing and deployment, reducing latency and increasing scalability.

In essence, the integration of AI, ML, and web technologies is what transforms digital humans from static figures into intelligent, adaptive, and interactive entities. These advancements make digital human's viable tools for communication, education, health services, and entertainment, further bridging the gap between human cognition and machine automation.

2.0 Methodology

Our methodology encompasses both quantitative and qualitative methods, as we seek to blend the power of statistical analysis with the richness of in-depth interviews and surveys. The methodology serves as the cornerstone of our research, ensuring that our study is structured, rigorous, and developing an interactive and intelligent digital human capable of simulating realistic human behavior and communication. As part of data sourcing and integration, specific software tools were used to collect, manage, and analyze data. These include:

1. **Google Forms:** For user survey and structured data collection.
2. **NVivo:** For coding and analyzing qualitative interview data.
3. **Figma & Adobe XD:** For prototyping and mapping user interaction feedback.
4. **Visual Studio Code & XAMPP:** As the primary development environment.
5. **MySQL Database:** For storing user interaction logs during test runs.

2.1 Existing Digital Assistant and AI-Human Interface Platforms

Over the past decade, the digital assistant landscape has expanded rapidly, driven by advances in artificial intelligence (AI), machine learning, and natural language processing (NLP). Digital assistants, also known as AI-human interface platforms, are systems that simulate human conversation and perform tasks based on user input.

Google Assistant: Google Assistant is one of the most advanced voice assistants. It integrates deeply with Google's services and supports contextual conversation, multilingual responses, and proactive task management. It uses deep neural networks and leverages the capabilities of Google Search and Google Lens to offer personalized and accurate responses (Wang & Eskenazi, 2019).

Amazon Alexa: Alexa, Amazon's AI assistant, focuses on home automation, task scheduling, and e-commerce integration. Alexa runs on a cloud-based platform that processes and analyzes voice inputs using Amazon Web Services (AWS), employing deep learning models to improve over time (Guzman & Lewis, 2020). However, its scope is limited in regions with poor internet infrastructure, making it less accessible globally.

Apple Siri: Siri, integrated into Apple devices, emphasizes security and privacy, processing many tasks on-device. While its conversational depth is not as robust as newer models, its integration across the Apple ecosystem makes it intuitive for users in that ecosystem. Siri uses a combination of rule-based logic and machine learning for predictive responses (Hoy, 2018).

ChatGPT and OpenAI Assistants: ChatGPT represents a new generation of digital human interfaces based on generative transformers. It supports highly contextual dialogue and memory features, depending on the version. These assistants can be integrated via API into different applications and websites, allowing developers to create customized human-like agents (OpenAI, 2023).

Meta's AI Avatars (e.g., Meta AI and Codec Avatars): Meta has developed photorealistic avatars, combining computer vision, speech synthesis, and emotion recognition. Their Codec Avatar project aims to produce ultra-realistic digital humans capable of mimicking expressions and gestures in real-time virtual spaces (Zhang et al., 2021).

3.0 Results and Discussion

3.1 Results

The developed digital human system proved effective in creating interactive, human-like conversations using common web technologies such as PHP, JavaScript, SQL, HTML, and CSS. During testing, the system showed clear improvements in usability, personalization, and overall user satisfaction when compared with established platforms like Siri, Google Assistant, and Alexa.

One of the most significant outcomes was its ease of use and accessibility. Because the system runs entirely in a browser without requiring powerful hardware or virtual reality tools, it can be accessed even in low-resource environments.

Another major achievement was personalization through memory retention. By storing past interactions in a MySQL database, the digital human could recall user information across sessions, creating more natural, context-aware conversations.

Although the system only featured basic emotional responses, these still made the interactions feel more engaging than traditional chatbots. This was achieved through keyword recognition and simple contextual cues. In addition, the system supported multimodal interaction, combining text, speech, and an avatar with basic facial expressions. Feedback from users was largely positive. Participants appreciated the faster responses, smoother interaction flow, and the potential for applying the system in education, healthcare, and customer service.

6.2 Discussion

The findings suggest that digital humans can move beyond the limitations of existing assistants by offering context-aware, emotionally engaging, and scalable interactions. While popular platforms like Alexa and Siri are intelligent and highly integrated into their ecosystems, they lack long-term memory, cultural adaptability, and lightweight deployment options areas where this project provided a clear advantage.

6.2.1 Practical Implications

The prototype demonstrates significant potential across multiple sectors. In education, it can function as a virtual tutor, providing consistent lessons while adapting responses to individual learners. In healthcare, it could operate as a mental health companion or digital receptionist, thereby reducing staff workload and offering emotional or informational support. Within customer service, its capacity to recall past conversations enhances efficiency in issue resolution and strengthens user trust.

6.2.2 Strengths

The system offers several notable strengths. Its browser-based nature ensures scalability, allowing it to serve a large number of users simultaneously. Built on open-source technologies, it remains affordable by avoiding the high expenses associated with proprietary platforms. Furthermore, its modular design enables flexibility, permitting easy adjustments to dialogue structures, behavioral patterns, and avatar appearances.

6.2.3 Limitations

Despite its achievements, several limitations persist. The system’s emotional intelligence remains rudimentary and lacks the capacity to fully express empathy. Although multilingual support is available, it requires substantial enhancement to effectively reach global audiences. Similarly, non-verbal communication—such as gestures and facial expressions—remains relatively basic when compared to more advanced augmented or virtual reality avatars.

6.2.4 Ethical and Technical Concerns

As with other AI-driven systems, ethical and technical considerations are critical. The project must address potential bias in training data and uphold academic integrity, particularly in educational applications. Building trust with users will depend on ensuring transparency, fairness, and adherence to clearly defined ethical guidelines.

Future work will focus on integrating state-of-the-art natural language processing models, such as BERT and GPT, to create more natural and coherent dialogue. Emotion recognition tools will be developed to foster greater empathy in conversations. Efforts will also explore immersive interfaces through AR, VR, and GAN-based avatars to enrich user experiences. Additionally, expanding offline and mobile capabilities will improve accessibility in regions with limited internet connectivity.

Overall, the project illustrates that digital humans can evolve beyond task-specific functions to become scalable, adaptive, and emotionally engaging companions. Their continued success, however, depends on balancing technological innovation with ethical responsibility—reducing bias, ensuring fairness, and maintaining the indispensable human element in education, healthcare, and customer service.

7.0 Conclusion

This project successfully developed a functional and interactive digital human capable of simulating human behavior, responding intelligently to user queries, and engaging in emotionally aware communication. A review of existing systems such as Siri, Google Assistant, Alexa, and Samsung's NEON revealed gaps in long-term memory, emotional depth, cultural adaptability, and deployment efficiency in low-resource settings. To address these limitations, a new prototype was built using PHP, JavaScript, SQL, HTML, and CSS, integrating real-time conversational processing, memory retention through MySQL, and adaptable language options.

The resulting system proved scalable, user-friendly, and emotionally engaging, offering significant improvements in personalization and accessibility. Its modular architecture and cross-platform compatibility make it suitable for diverse applications, including education, healthcare, customer service, and digital companionship. The project demonstrates that digital humans can move beyond routine task execution to become emotionally intelligent virtual agents capable of meaningful human-like interaction.

By combining empirical insights with modern AI tools, the study contributes to the advancement of human-computer interaction and establishes a foundation for future innovation in immersive and responsive digital companions. Continued progress in this field will depend on integrating advanced NLP models, emotion recognition, multilingual support, and offline capabilities while maintaining ethical data use and encouraging open-source collaboration.

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Declarations

Ethics and Consent to Participate

Not applicable.

Consent to Publish

Not applicable

Availability of data and materials

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Authors' Contributions

Prisca I. Okochi conceived and supervised the study, guided system design, and reviewed the manuscript. Agbasonu V. C. developed the

system, handled coding, integration, and testing. Comfort C. Olebara conducted terature review, data collection, and usability evaluation. All authors approved the final manuscript for publication