A Study on Wearable Tech Interfaces and Perception: Cognitive AI-Enabled Device

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Abstract—**In our paper, we explore the possibility of utilizing state-of-the-art hardware architecture to develop an interactive Artificial Intelligence(AI) based virtual agent in an Internet of Things (IoT) enabled smart glass. In contrast to the traditional system that relies on Central Processing Unit(CPU) and Graphical Processing Unit(GPU), we examine the possibility of a proposed hardware system that employs neuromorphic computing for precise and energy-efficient processing in real-time, resolving the problems of latency and excessive power consumption. When combined with conventional Complementary Metal-Oxide-Semiconductor (CMOS) technology, Resistive Random Access Memory(ReRAM) offers non-volatile, fast memory that facilitates parallel computing and guarantees smooth data store and retrieval for wearables with limited resources. This study also emphasizes the application of intelligent virtual agents based on cognitive AI in wearable technology. In order to create an immersive human-computer interface, we attempted to create an intelligent interactive AI avatar with Cycle Generative Adversarial Network (CycleGAN) that mimics the user's traits and further pushes it to the large Language Model(LLM) to generate motion sequences that perform additional tasks, transforming LLM prompt reactions into movements.**

Keywords - Smart glass; virtual avatar; AI-enabled device; GANs; ReRAM

I. INTRODUCTION

Augmented reality (AR) glasses, also known as simulated reality glasses, are innovative wearable devices that overlay digital information onto the user's physical surroundings. These devices leverage advanced displays to enable users to visualize and interact with virtual objects seamlessly integrated into their three-dimensional environment [8] [9] [10] [11] [12] [13] [14] [15] [16] [17]. By employing technologies such as cameras and sensors, AR glasses deliver a highly interactive augmented reality experience. This technology bridges the gap between the real and virtual worlds, offering users access to an expansive array of information that would otherwise remain inaccessible in their daily reality [8][13][14][15][16][17].

AR glasses have found applications across diverse industries such as gaming, education, healthcare, engineering, and entertainment. For instance, in education, AR glasses create immersive and interactive learning experiences, enabling students to grasp complex concepts more effectively through visualization. In healthcare, these devices assist surgeons by providing real-time data during procedures, enhancing precision and outcomes [1][2][3][4][5][6][7]. The potential of AR glasses extends far beyond these fields, promising transformative impacts across a wide range of sectors.

As hardware and software technologies evolve, AR glasses continue to improve at a rapid pace. High-resolution Micro Light Emitting Diode (MicroLED) and Organic Light Emitting Diode(OLED) displays enhance visual quality and color rendering, offering more realistic augmented experiences [18]. Miniaturization of components such as cameras and sensors has resulted in lighter, more user-friendly designs. Additionally, advanced System-on-Chip (SoC) architectures and powerful processors facilitate real-time processing of complex AR interactions, while depth sensors and improved cameras enhance environmental mapping and object positioning [19] [20] [21] [22] [23] [24] [25] [26] [27].

Software advancements further amplify the capabilities of AR glasses. Machine learning algorithms enhance object recognition and scene understanding, enabling smarter and more intuitive interactions. Cloud-based processing reduces the computational burden on local devices, while gesture and voice-control technologies make applications more accessible. Development tools like ARKit and ARCore streamline the creation of AR content, accelerating innovation in this field [13] [14] [15] [16] [17].

Looking ahead, AR glasses hold immense promise. In medicine, they provide surgeons with crucial overlays of information, enhance medical training through simulations, and support real-time diagnostics [1][2][3][4][5][6][7]. In education, they foster engaging learning environments where students can interact with virtual 3D models to deepen their understanding [31] [32] [33]. The retail industry benefits from AR glasses through virtual try-ons for clothing and furniture visualization in homes. Remote collaboration is also enriched, allowing users to share views and opinions in real-time, thereby improving teamwork and project management [28][29][30][34][35][36][37][38][39].

In navigation, AR glasses overlay turn-by-turn directions, simplifying travel in unfamiliar places. For gaming, the integration of digital content with the real world creates immersive, interactive experiences. In the workplace, employees can access real-time instructions and visuals to boost efficiency and reduce errors. Furthermore, AR glasses enhance urban living by providing real-time updates on traffic and points of interest, promoting smarter city interactions. They also support task management by displaying schedules, reminders, and essential information directly in the user's field of vision. Advances in display technologies, such as energy-efficient MicroLEDs and OLEDs, along with waveguides and laser-based light direction systems, are revolutionizing AR glasses [18]. Sensor innovations, including eye-tracking and depth sensors like Light Detection and Ranging (LiDAR), improve interaction accuracy and environmental mapping. Neuromorphic chips and AI-powered computer vision enable ultra-fast processing for real-time recognition of objects and scenarios [19][40][41][45][46][47][48][49][50]. Emerging technologies like edge computing, spike neural networks, and energy-harvesting systems ensure AR glasses are increasingly efficient and sustainable [19][42][43][44] [20] [25] [26] [27]. Privacy concerns are addressed with on-device processing, minimizing reliance on cloud systems.

The integration of embodied virtual assistants further enriches the AR experience. These AI-driven agents, with lifelike 3D bodies and natural speech, create engaging, human-like interactions. This is particularly relevant in applications like reinforcement learning and self-learning, where such agents facilitate intuitive learning and problem-solving. The development of interactive AR glasses parallels advancements in information and communication technologies, with embodied agents demonstrating greater emotional resonance and realism than their disembodied counterparts [13] [17].

While AR and virtual reality (VR) technologies offer significant potential, challenges remain. Current VR systems face limitations such as artifacts, occlusion effects, and high computational demands. Innovations like next-generation controllers, wireless headsets, and improved interfaces are needed to address these issues and reduce costs [31] [32] [33]. Despite these hurdles, AR and VR continue to evolve, offering groundbreaking applications in language learning, collaborative work, and immersive training environments.

In conclusion, we propose the development of a smart AR headset integrated with an intelligent avatar that adapts to the user's identity. Powered by technologies like CycleGAN for personalized avatar creation, Generative Pretrained Transformer (GPT-4o) for speech-to-motion conversion, and a cost-effective hardware architecture using ReRAM and Neuromorphic Processing Units (NPU), this headset promises to redefine the AR experience. The key contributions of this proposal include:

- Personalized Avatars: Utilizing Cycle Generative Adversarial Network (CycleGAN) to generate avatars reflective of individual user identities.
- Actionable Prompts**:** Leveraging large language models (LLMs) to translate user prompts into dynamic actions or motions.
- Optimized Hardware**:** Implementing resource-efficient architectures with Resistive Random Access Memory (ReRAM) and Neuromorphic Processing Unit (NPU) for enhanced performance at reduced costs. This vision paves the way for a revolutionary shift in augmented reality, empowering users across multiple domains to achieve new levels of interactivity and functionality.

Our proposed idea can be depicted by the following diagram:

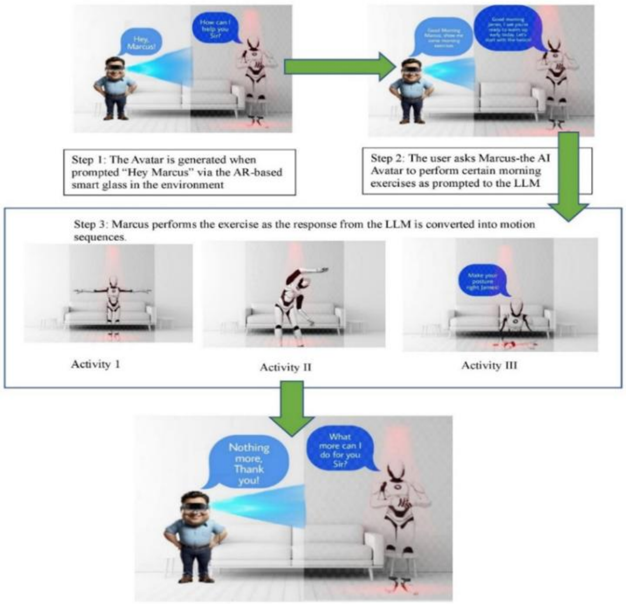

Fig I: An example of how the AI agent reacts to a prompt given by the user requesting the virtual avatar to show some morning exercises

This idea which is described in the above figure I can be generated by using the following architecture in an IOT-enabled device which is a smart glass in this case:

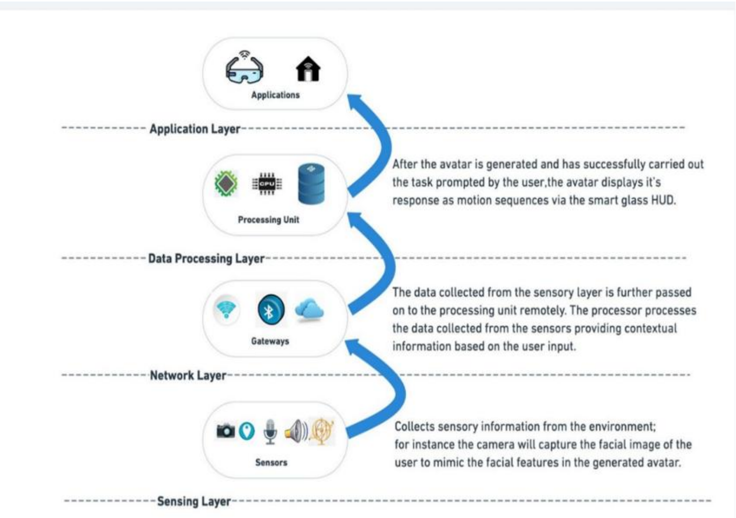

Fig II: System Architecture of the complete IOT-enabled device

The AR-based smart glass's system design combines networking, software, and hardware elements to deliver smooth augmented reality experiences. Real-time processing, user engagement through the use of an intelligent agent in the system's operating system, and flexibility to accommodate a variety of use cases are all guaranteed by the architecture's modular design.

The device layer, also known as the sensing layer, is the first layer of the system's straightforward four-layered design. It collects real-time environmental and user input, such as the user's image and personal information, in order to replicate the user's face features. The data is subsequently sent to the network or communication layer (Fig II), which enables real-time data transfer between the IOT-enabled smart glass and additional edge devices.

The third tier of the architecture, also known as the processing layer, is where the system's brain is located and where the data is further processed. Here, the avatar is created using facial data, and contextual information is processed in response to human input to create motion sequences. Together with the neuromorphic processing unit, which is in charge of converting Artificial Neural Network (ANN) weights to Spiking Neural Network (SNN) and then forwarding the data to the system's final layer, or application layer. The ReRAM serves as both the RAM and the processor in this case, allowing parallel computing processing user commands and contextual information. The application layer shows the output that the user requested through the interactive, lifelike virtual avatar that shows real-time data via the smart glass Heads Up display (HUD).

II.METHODOLOGY

This section introduces our proposed system: a smart glass with an interactive virtual intelligent agent leveraging augmented reality. The system is divided into two primary components—software and hardware. The software implementation includes two processes: (2.1.1) creating a virtual avatar and (2.1.2) instructing the intelligent avatar to perform specific tasks. The proposed hardware architecture incorporates several key components aimed at reducing cost and resource usage. These include sensors, a battery, a display module, and ReRAM (a memristor-based processor-in-memory unit designed for handling complex calculations and parallel computing). Additionally, advanced decision-making and other machine intelligence tasks will be managed by a neuromorphic processing unit utilizing a spin-Naker architecture.

2.1 Implementation of the software

We break the implementation of the software into the following two steps as discussed above.

2.1.1 Generation of the virtual avatar using CycleGAN

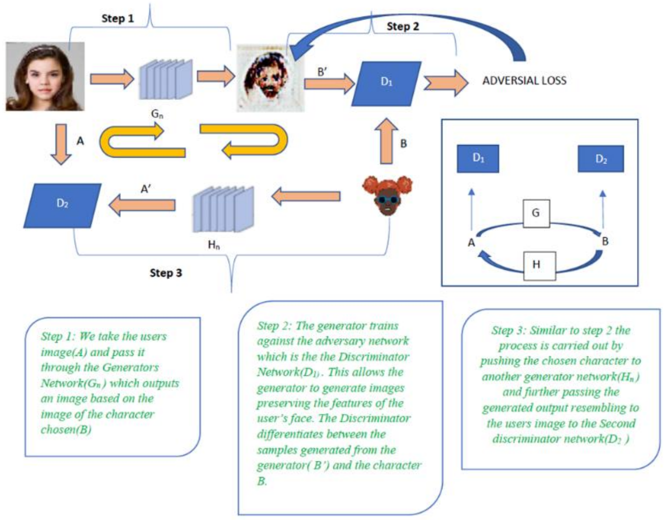

Fig III: The image shows the pipeline for the generation of the avatar with G and H being the generator network and D being the discriminator network

We employ Cycle Generative Adversial Neural Network (CycleGAN), as illustrated in Fig. III, to transform the user's image into a distinct character that retains certain features, such as facial structure and hairstyle. This study utilizes two datasets: Dataset A, the CelebA dataset, which contains approximately 20,000 images of famous faces, and Dataset B, which includes cartoon faces. CycleGAN performs exceptionally well in unpaired image-to-image translation tasks, making it an ideal choice for this application.

The CycleGAN architecture consists of two generator networks: one transforms the user's original image into a cartoon face, while the other attempts to revert the cartoon face back into the original face. Notably, the reverted face is synthetic but closely resembles the user's original features. Complementing the generator networks are two discriminator networks: one evaluates whether an image is a real or generated cartoon face, and the other determines whether an image belongs to the user.

A key feature of CycleGAN is cycle consistency loss, which ensures that when a user's face is transformed into an anime face and then reverted, the final image remains similar to the original. This guarantees that essential facial characteristics are preserved during the transformation and reconstruction processes.

2.1.2 Passing instruction to the generated avatar using GPT4-o-mini

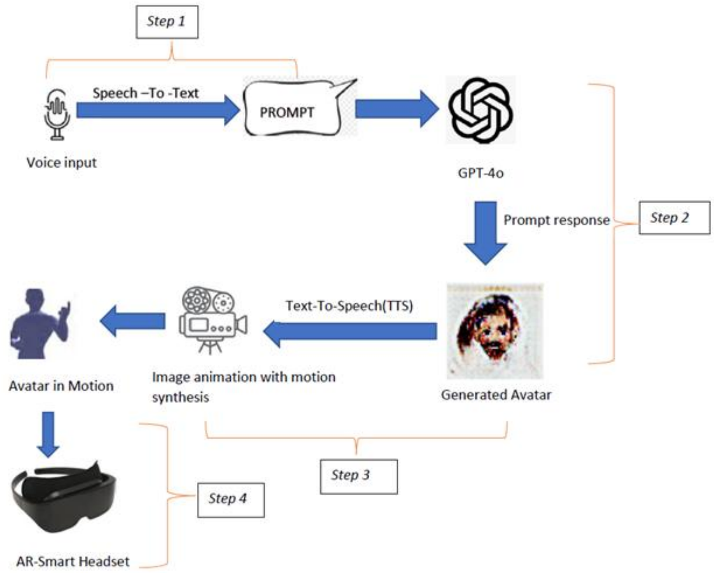

Fig IV: The image shows the pipeline to carry out user's instruction in motion

Step 1: User sends command to the generated avatar using the microphone as voice input which is then converted from speech to text

Step 2: The text generated is passed as prompt to the LLM model which is GPT-4o in this case. The LLM generates response based on the users query and passes on to the generated avatar

Step 3: The generated avatar along with the prompt response is pushed into Dynamic Image Distillation, DID (an image animation software) that creates frames with motion synthesis

Step 4: The avatar in motion is viewed through the AR glass

In the second step as shown in figure IV we try to perform motion synthesis technique with Dynamic Image Distillation (DID). Here the generated avatar image is pushed as an input to the model of Dynamic image distillation where it extracts key visual features and then creates motion pattern and then by using generator network it creates frames. This kind of model can be found in software like D-ID or deep motion. We further implement a Large Language Model(LLM) in this case it is GPT-4o-mini that provides instructions as a response from the prompt by the user by converting them into motion vectors which is then fed into the generative model for further generation of motion.

The D-ID is integrated with the LLM taking the generated avatar as an image input and further animating the image of the avatar based on the response of the LLM. In this study, we explore the application of zero-shot prompting to evaluate the system since the model was not explicitly fine-tuned on specific motion sequences and is performing its action based on the prompt information provided.

2.2 Proposed Hardware Architecture

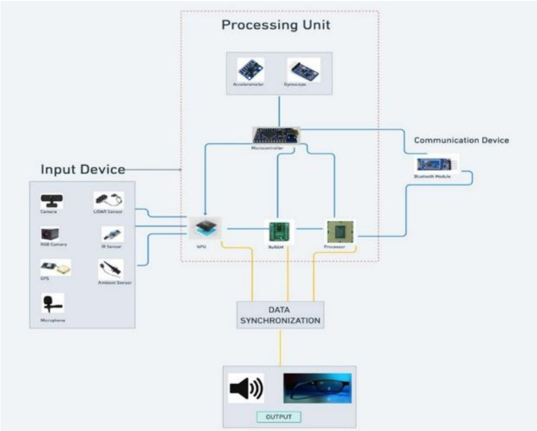

Fig V: The figure shows the proposed hardware architecture

As shown in the figure V, the architecture follows Multiple Instruction Multiple Data(MIMD) parallel computing within the processors. Apart from a traditional CPU and a GPU this architecture consists of a ReRAM and an Neuromorphic Processing unit(NPU). The sensors that shall be used are Lidar Sensor, IR sensor, Ambient sensors, RGB camera, depth of field cameras, and a GPS. Along with the sensors, Inertial Measurement units (IMU) like Accelerometer and gyroscope shall be used.

2.2.1 Integration of Resistive Random Access Memory(ReRAM) with Neuromorphic Processing Unit(NPU)

ReRAM is a non-volatile computing in memory chip that works by interchange of resistance with an ability to scale below 10nm. Thus displaying a capacity of higher storage in smaller chip sizes, it proves to be a systematized complement to the traditional DRAM which is generally used as an external RAM. Here we are going to integrate the ReRAM as a potential memory element as well as a processor in combination with the spinnaker-based NPU unit as shown in Fig V. Earlier research has shown ReRAM to be an effective memristor capable of reducing power consumption thus making it energy efficient. Here in the proposed architecture, we explore its potential for effective computing in combination with the Neuromorphic processing unit by shared memory system and parallel computing where the NPU will convert the Artificial Neural Network (ANN) features into spikes and pass them to the ReRAM. The ReRAM will be assigned the task of storing synaptic weights, performing feature extraction by executing complex matrix-vector multiplication, and performing spike encoding directly in the memory, with the capability to save the previous state even when the system is powered off. The user's face image is first taken by the camera in conjunction with the RGB camera for the Avatar Generation assignment. The GPS module, which is used to set up the AR environment, also records the area's location in addition to the image. When the user prompts the system, the processing unit processes the speech input from the microphone in parallel to minimize delay (Fig. V). The software's answer is displayed in motion on the Smart Glass HUD.

III. RESULTS AND CONCLUSIONS

In this section, the effectiveness of the hardware and software components of the system, a smart glass with an interactive virtual intelligent agent is discussed. The suggested system's hardware has been evaluated on a virtual simulator, resulting in a design that is both economical and resource-efficient. The outcomes indicate notable improvements, such as reduced latency and a 15% increase in energy efficiency due to lower power consumption. However, to ensure the robustness and scalability of the architecture under varying conditions, further research is necessary, as the current study is limited to a specific workload and particular computational components that integrate CMOS with memristors. Despite these limitations, the proposed architecture lays a foundation for developing an economical, energy-efficient, and high-performing device, with future research expected to yield significant advancements in the hardware industry.

To evaluate the fidelity, consistency, and quality of the generated images, the AI avatar constructed using the user's facial features with the CycleGAN model was assessed using both qualitative and quantitative criteria. After training for 100 epochs, the model's performance was evaluated quantitatively (Table I) and qualitatively, with approximate scores summarized as follows:

EVALUATION METRICS	SCORE
Frechet Inception Distance (FID)	50.67
Perceptual Loss (PL)	0.18
Structural Similarity Index (SSIM)	0.83
Cycle Consistency Loss	0.244
Inception Score (IS)	4.13 ± 0.14
Peak Signal-to-Noise Ratio (PSNR)	25.4 dB

Table I: Cycle GAN Architecture Evaluation Results after 100 epochs with image size of 64 *64

In addition to the quantitative assessment, a qualitative evaluation was conducted:

1. **Human Evaluation:** Twenty volunteers participated in a user study where they selected the type of avatar they preferred as their AI companion. The results

showed that 65% of participants chose the generated avatar as their personal agent.

2. **Testing Image Samples:** The conversion of user faces into anime-style avatars demonstrated that the model generally retained the user's facial features while effectively capturing anime characteristics.
3. **Motion Synthesis Capabilities**: To evaluate the avatar's motion generalization abilities, the system was tested using zero-shot natural language prompts. For example, one prompt was: "Tell a story about a courageous king who embarks on a mission to rescue a princess trapped in a forest. Explain the princess's body language and facial gestures as she is stranded in a jungle." The generated avatar successfully conveyed the expression of "fear," but ambiguous results were observed for certain complex tasks. Nevertheless, the system effectively produced context-relevant motion responses for a variety of simpler tasks.

In conclusion, this study presents a smart augmented reality-based headgear with a proposed hardware architecture that enhances energy efficiency and an intelligent agent capable of interacting with the user to simplify their daily activities. The system leverages an NPU and a non-volatile memory unit to achieve efficient computation. By integrating these components with parallel computation, the system overcomes computational bottlenecks and high power consumption issues, enabling faster boot-up times and data access. This is particularly crucial for performance-intensive tasks like generating avatars based on user facial features with reduced latency.

The system becomes more engaging and personalized for users due to the AI agent developed with CycleGAN. However, the system still faces challenges related to hardware scalability, the integration of non-volatile circuits with CMOS technology, and handling complex tasks, such as the smooth transition from ANN to SNN. Additionally, the creation of realistic avatars requires a diverse and carefully curated dataset, which remains resource-intensive and costly. Despite these challenges, this work establishes a strong foundation for future advancements. The findings suggest that further developments in hardware optimization, cognitive approaches—such as incorporating emotional intelligence to recognize user emotions and respond appropriately with additional sensory inputs—and improvements to the CycleGAN architecture with implementation of SpikeLLM's could lead to a more intelligent, efficient, and customized devices.

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