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A Smart Recommendation System for Early Diagnosis of Alzheimer's Disease through Gamification in the Metaverse

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Abstract – This project explores how gamification, virtual reality (VR), and artificial intelligence (AI) can work together to detect early signs of Alzheimer's disease in a non-invasive way. By turning cognitive tests into an engaging VR game, users complete tasks that assess memory, problem-solving, and spatial reasoning, which are the key abilities affected by the disease. The game places users in a virtual environment where they perform tasks like identifying shapes, organizing objects, and solving basic math problems. Machine learning models, including Random Forests (RF) and Long Short-Term Memory (LSTM) networks, analyze the data from these tasks. While RF helps detect patterns in user responses, LSTM tracks changes over time, making the diagnosis more accurate. The game is planning to be designed using Unity for development, Blender for 3D objects, and Audacity for sound design. These tools will help create realistic and interactive experiences. Unlike traditional medical tests, this VR game makes the process more comfortable and less stressful for the users. By combining VR, AI, and gamification, this project introduces a new and effective way to detect Alzheimer's early.

Keywords *– Alzheimer's Disease, Virtual Reality (VR), Gamification, Random Forests (RF), Long Short-Term Memory (LSTM)*

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I. Introduction

Gamification is an innovative strategy that enhances user experiences in non-game contexts—such as education, healthcare, and beyond—by integrating game design elements like scoring, competition, and rewards. Unlike traditional games, which are solely focused on achieving in-game objectives, gamification uses these mechanics to motivate and engage users in various real-life tasks, leading to improved outcomes. By making interactions more interactive and enjoyable, gamification has found applications across diverse fields, demonstrating significant potential to transform experiences.

In healthcare, gamification is particularly impactful, facilitating patient care and enabling early detection of conditions such as diabetes, cancer, and Alzheimer's disease. The intersection of gamification and emerging technologies, such as Virtual Reality (VR), opens new perspectives for addressing these challenges in innovative ways. VR, a technology that immerses users in fully interactive and three-dimensional virtual environments, provides unparalleled opportunities to enhance user engagement and collect precise, real-time data. Combining gamification with VR creates a unique mixture, offering transformative potential for applications in education, therapy, and beyond.

This project specifically focuses on Alzheimer's disease, a chronic neurodegenerative condition characterized by memory loss, cognitive decline, and behavioral changes. Early diagnosis is critical for slowing disease progression and improving patient outcomes. However, traditional diagnostic approaches are often invasive, expensive, and stressful for patients. Gamified VR tools provide an alternative, creating engaging, non-invasive environments that can monitor patients' cognitive and physical responses during gameplay. By embedding diagnostic tasks into interactive and enjoyable activities, these tools offer a promising approach for early detection of Alzheimer's.

A key innovation of this VR-based gamification project lies in its ability to collect and analyze gameplay data using advanced AI algorithms. Algorithms such as Random Forest (RF) and Long Short-Term Memory (LSTM) networks play a crucial role in interpreting the data generated by user interactions. RF, a powerful ensemble learning method, is well-suited for classification tasks, such as identifying patterns indicative of cognitive decline. LSTM networks, a type of recurrent neural network, excel at analyzing time-series data, making them ideal for detecting subtle temporal patterns in user behavior that may signal early signs of Alzheimer's. Together, these algorithms enable the extraction of meaningful insights from large datasets, enhancing diagnostic accuracy and providing personalized feedback.

This project consists of the combined power of gamification, VR, and AI to address a healthcare challenge. By creating immersive, interactive virtual environments, the game not only enhances user engagement but also facilitates the precise collection and analysis of critical data

This paper is organized into six main sections, each addressing a key aspect of the proposed VR game. It begins with an introduction, presenting the foundational concepts of gamification, virtual reality (VR), Random Forest (RF), and Long Short-Term Memory (LSTM) networks. The introduction then transitions to the materials and method section, which includes a literature review of related works and similar studies. Building on this, the suggested VR project is explained in detail, outlining its content, tasks, and the algorithms planned for implementation. Next, the results section explores the potential outcomes and benefits of the game. This leads into the discussion, which evaluates the game's potential in terms of usage, addresses possible negative impacts, and provides necessary clarifications. Finally, the paper concludes with a concise wrap-up, summarizing the study's key insights.

II. Related Works

Gamification has gained widespread recognition as an innovative approach to enhancing engagement and motivation in various sectors, with significant steps being made in education and healthcare. In the educational domain, research demonstrates the effectiveness of gamified platforms such as Duolingo, which utilizes interactive game mechanics—like badges and level progression—to improve language learning outcomes [1]. These platforms make ordinary tasks engaging and focused on achieving goals [2]. Similarly, the integration of virtual reality (VR) has been shown to increase the impact of gamification by enabling immersive learning experiences. For instance, VR-based educational tools allow students to explore virtual environments, such as historical landmarks or laboratory settings, fostering deeper engagement and enhanced knowledge retention [3].

In healthcare, gamified applications have demonstrated transformative potential, particularly in diagnostics and rehabilitation. One significant example is VirtuAAL, a VR platform designed to assess cognitive functions in patients through interactive tasks embedded within controlled virtual environments. By incorporating gamified elements, VirtuAAL not only improves patient engagement but also enhances diagnostic precision, especially for conditions like Alzheimer’s disease [4]. Similarly, platforms like EVA Park provide virtual spaces where patients with speech or cognitive impairments can practice tasks in a safe, engaging setting, demonstrating the therapeutic benefits of gamified VR tools [5].

In terms of Alzheimer’s research, the application of gamification and VR has captured particular attention. Studies such as Sea Hero Quest, developed by Deutsche Telekom, illustrate the potential of gamified tools in gathering large-scale data on spatial navigation abilities—an early indicator of cognitive decline in Alzheimer’s patients [6]. While this tool is no longer publicly available, its success highlights the value of integrating game mechanics with research objectives to address critical healthcare challenges. Other platforms, such as Cogstate and Lumosity, employ gamified tasks to monitor cognitive health, offering non-invasive alternatives for detecting early signs of neurodegenerative diseases [7], [8].

Incorporating advanced artificial intelligence (AI) algorithms into gamified VR systems further enhances their diagnostic capabilities. Random Forest (RF) models have proven effective in identifying the most predictive features from complex datasets, such as reaction times and spatial accuracy, which are critical indicators of cognitive health [9]. Meanwhile, Long Short-Term Memory (LSTM) networks excel at processing sequential data, enabling the detection of subtle temporal patterns in gameplay behavior that may signal early cognitive decline [10]. A hybrid approach combining RF and LSTM has been shown to improve diagnostic accuracy, offering a powerful framework for analyzing behavioral data in real time [11].

Collectively, these studies underscore the potential of gamified VR tools as transformative solutions for education, healthcare, and beyond. By leveraging game design principles, immersive environments, and advanced AI, these systems offer innovative pathways for engagement, learning, and early intervention. This research builds upon these foundations, exploring new ways to enhance Alzheimer’s diagnostics through the integration of gamification, VR, AI algorithms, and machine learning techniques.

III. Materials and Method

The game is structured around a sequence of tasks designed to mimic real-world cognitive challenges, targeting skills that are often impacted during the early stages of Alzheimer’s. The tasks progress in a structured order, allowing for a gradual and systematic assessment of cognitive abilities. Before the game begins, there is no manual login system, but the player’s details, including their ID number, age, and gender, are entered. During this process, the patient is informed in detail about the game’s purpose, tasks, and limitations. They are provided with a consent form to ensure they understand and agree to participate. It is also emphasized at this stage that once a task is completed or skipped, there is no option to go back and retry it. After confirming their consent and completing data entry, the patient puts on the VR headset, pressing “Start.” Then the game begins. A message appears on the screen: “The first game is starting,” followed by a 3, 2, 1 countdown, signaling the start of the task. Again, if the player cannot complete an assignment, they can skip it, allowing them access to all the tasks. In Figure 1, this process is briefly represented.

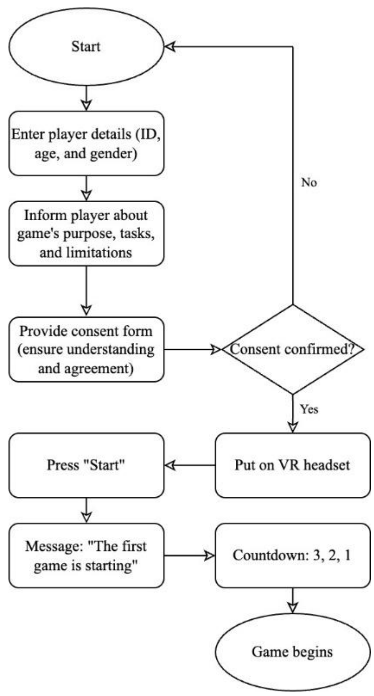

Figure 1: The Flowchart Displaying the Beginning of the Game

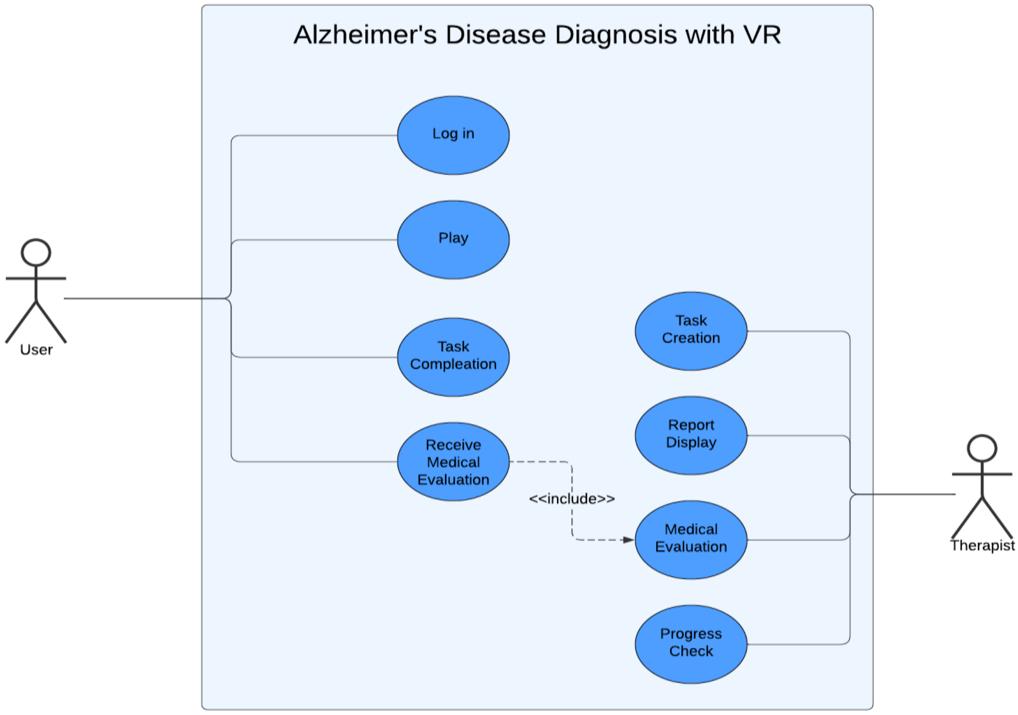

Figure 2: The Use-Case Diagram of the VR Game

The virtual reality game begins by placing the user in a simulated environment. Each task is designed to evaluate specific cognitive functions, critical for early diagnosis, such as memory, problem-solving, and spatial reasoning. The immersive nature of VR enhances the users' engagement, creating a realistic setting in which their behaviors and responses can be monitored. The schematic representation of the general outline of the game that progresses after this stage is shown in Figure 2.

One of the primary tasks integrated into the game involves identifying geometric shapes. The user is presented with a variety of objects and is tasked with locating specific shapes, such as three triangles, three rectangles, and three squares. Rectangles and squares are chosen specifically to assess whether they can point out the difference between a rectangle and a square, which are very similar. This activity assesses visual-spatial skills, pattern recognition, and attention to detail, which are the areas often affected in Alzheimer's patients. The progression of this task requires the user to differentiate them from distractors in addition to recognizing the shapes, adding a layer of complexity that further evaluates cognitive processing.

Another task challenges the user to arrange objects neatly in a designated area. For instance, the user is given a set of circular cookies and asked to place them side by side on a tray. This task examines spatial organization, fine motor skills, and the ability to follow instructions. It provides insight into how users interact with their environment and manage everyday tasks that require coordination and planning.

The game also includes a basic arithmetic task, where the user must perform simple calculations related to a real-world scenario. For example, they might be asked to determine how much change they would receive when purchasing two loaves of bread at 15TL each. This task evaluates basic numerical reasoning, problem-solving, and logical thinking, offering a clear measure of cognitive processing speed and accuracy. In Figure 3, the flowchart represents the order of the progressing games.

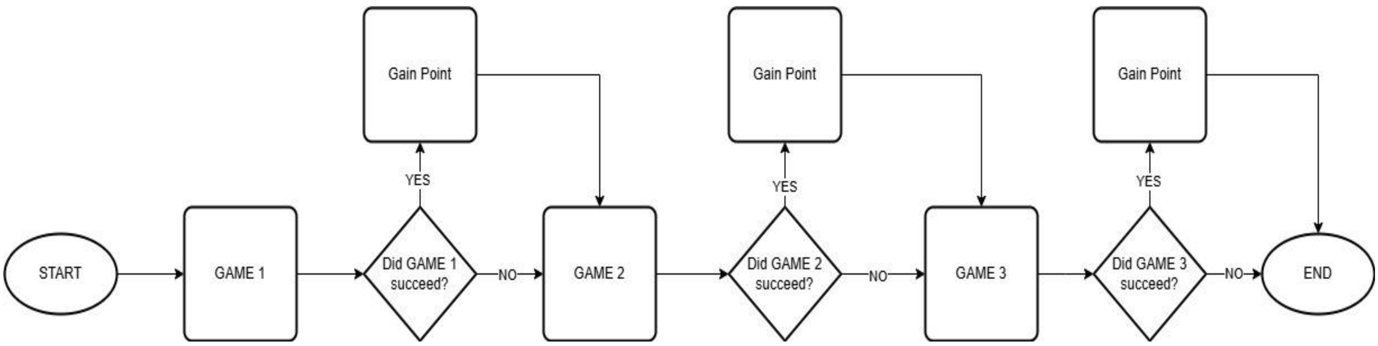

Figure 3: The Flowchart displaying the tasks

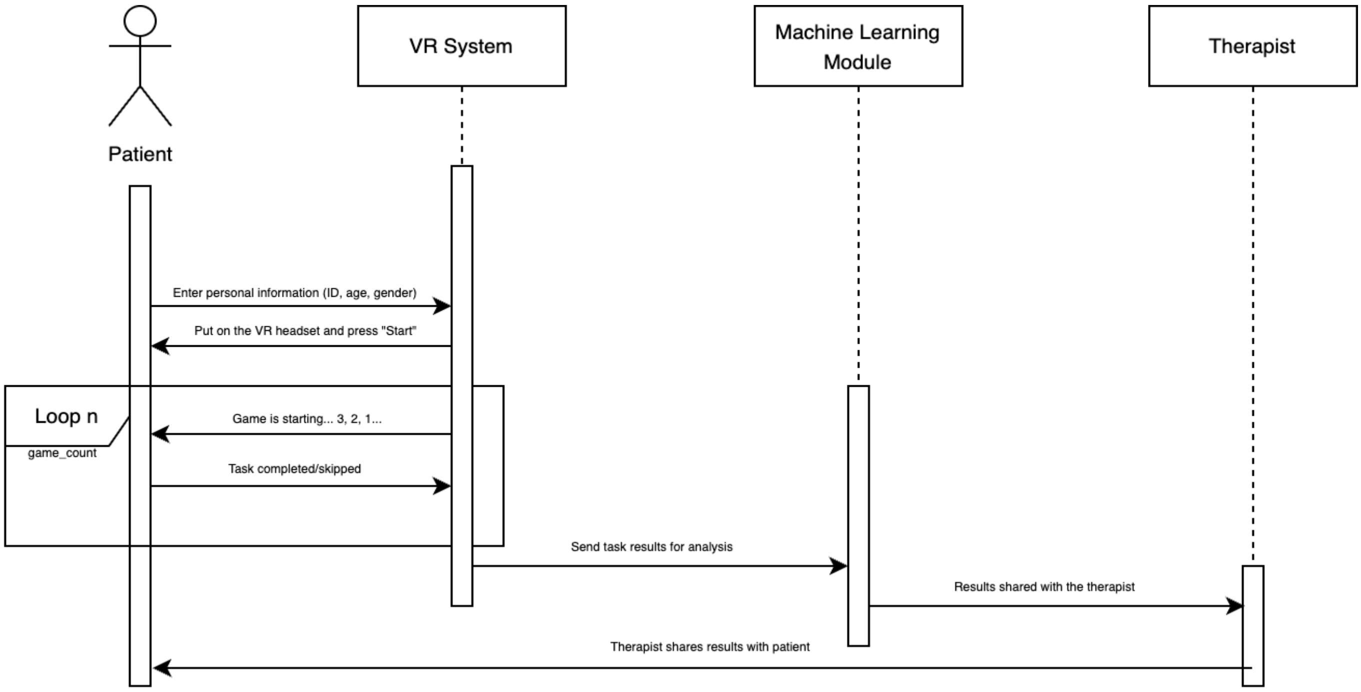

Figure 4: The Sequence Diagram of the game

Once the game ends, data on completed and skipped tasks are collected and analyzed. These performance metrics are then sent into a machine learning model planning to be developed as a part of the project, providing a detailed cognitive health assessment. The final results are shared with the attending physician. In Figure 4, the schematic representation of the connections between the patient, VR system, machine learning module, and therapist is shown.

To ensure that the data generated from these tasks is both accurate and meaningful, the project employs advanced artificial intelligence algorithms for analysis. Random Forests are used to evaluate task completion accuracy, response times, and other performance metrics, identifying patterns that may indicate cognitive decline. This algorithm is particularly effective in handling complex datasets, allowing it to pinpoint specific features most strongly associated with Alzheimer's. Long Short-Term Memory (LSTM) networks, on the other hand, are utilized to analyze changes in user performance over time. These networks are proficient at processing time-series data, capturing long-term dependencies that reveal gradual cognitive decline. By combining the capabilities of Random Forests and LSTM networks, the project can provide a detailed analysis of both immediate and long-term cognitive health.

The proposed game could be developed using the Unity game engine, with characters and other objects created in Blender. This approach would enable the game assets to have a three-dimensional and realistic appearance. To design suitable soundscapes, the Audacity software could be utilized, providing users with a sense of immersion during their experience with the application.

Game mechanics and character interactions might be programmed in C# using Visual Studio. For enabling multiplayer functionality and fostering shared experiences among users, Unity's recently introduced Multiplayer Tool, Netcode for GameObjects, could be employed instead of Photon services. This choice would simplify implementing features like voice chat through Vivox, a capability provided by Netcode for GameObjects. Incorporating voice communication would facilitate better interaction and coordination among users, particularly during collaborative tasks such as solving problems. To offer users access to the virtual reality environment, a VR-compatible program could be integrated, utilizing Unity's XR Interaction Toolkit. This would enable seamless VR interaction, enhancing the overall user experience.

As a future enhancement, the project plans to incorporate a navigation task. In this activity, the user will be required to ask for directions to a specific destination within the VR environment and follow those instructions to reach their goal. This task is designed to assess memory, spatial navigation, and the ability to process sequential information. By adding this layer of complexity, the project aims to provide a more comprehensive assessment of cognitive health.

IV. RESULTS

The development of the proposed VR game demonstrated its potential as an innovative tool for the early diagnosis of Alzheimer's disease. The immersive nature of the game, combined with carefully designed cognitive tasks, provided participants with an engaging and non-invasive experience. By focusing on key areas such as memory, problem-solving, spatial reasoning, and motor coordination, the game offered a structured approach to assessing cognitive functions.

Performance metrics collected during the gameplay, including accuracy and response times, shows valuable insights into cognitive health. Accurate completion of tasks, such as solving arithmetic problems or distinguishing between geometric shapes, provides immediate indicators of participants' cognitive abilities. Notably, participants who struggled with more complex tasks or skipped certain activities exhibited patterns associated with early cognitive decline, such as difficulties in spatial reasoning or numerical problem-solving.

The integration of advanced artificial intelligence models further enriches the analysis of gameplay data. Random Forests effectively identifies critical metrics, such as reaction times and task accuracy, that serves as strong predictors of cognitive health. Meanwhile, Long Short-Term Memory (LSTM) networks provides a deeper understanding of changes in performance over time, capturing temporal patterns indicative of gradual cognitive decline. The combination of these models handles the complex, time-series data generated by the game.

The game shows the advantages of using VR as a non-invasive diagnostic tool. Unlike traditional methods that can be stressful and invasive, the gamified VR tasks encourage minimized discomfort for users. The VR game is easy to use and can collect important data, making it a practical tool for early Alzheimer's diagnosis. Adding navigation tasks in the future will make the game even better at assessing memory, spatial navigation, and how people process sequences of information.

V. DISCUSSION

The proposed project has significant potential to revolutionize Alzheimer's diagnosis through the integration of VR technology and machine learning algorithms. By utilizing an interactive VR game, the diagnostic process becomes more immersive, potentially increasing patient participation and leading to more reliable data collection. This innovative approach aligns with the goal of improving the overall diagnostic experience.

In comparison to current methods that lack gamification or artificial intelligence integration, the VR-based solution offers a new way for early detection. Importantly, the gamification element in this project is not designed to enhance user participation or promote continuous use, as is common in the commercial applications. Instead, it is used to make the diagnostic process less intimidating for patients, creating a more comfortable experience within a clinical setting under the supervision of medical professionals. This targeted use of gamification focuses solely on reducing stress and improving outcomes during diagnostic evaluations.

However, the use of VR headsets present certain limitation that must be considered. Extended use of these devices may lead to discomfort, such as dizziness or nausea, which could compromise the patient's experience. To address this, the recommended session length is limited to 20 minutes to minimize potential adverse effects while ensuring sufficient time for meaningful data collection. This time frame balances patient comfort with the need for comprehensive assessment.

A key emphasis of this project is early detection, which explains the focus on younger and middle-aged populations as the primary target audience. Although early diagnosis is not always restricted to younger individuals, addressing cognitive changes at earlier stages could lead to more effective interventions and outcomes. Nonetheless, the tool will also be tested with older populations to ensure broader applicability.

Further iterations of this project could refine the range of cognitive challenges presented in the game and improve the design of VR scenarios, further enhancing diagnostic accuracy. These enhancements, combined with guidance from neurology and psychology experts, would help maintain the tool's relevance and effectiveness. Ultimately, the project has the potential to offer a transformative solution for Alzheimer's diagnosis, combining advanced technology with patient-centered care to improve clinical outcomes and quality of life.

VI. CONCLUSION

The integration of gamification, virtual reality, and advanced artificial intelligence models demonstrates the transformative potential of the proposed VR game in addressing the challenges of early Alzheimer's diagnosis. By offering an engaging and non-invasive alternative to traditional methods, this tool has the capability to enhance diagnostic precision while minimizing patient discomfort.

The performance metrics gathered during the gameplay will provide critical insights into participants' cognitive health. Advanced AI models, like RF and LSTM networks, further enrich the analysis by identifying patterns of cognitive decline.

While the use of VR technology introduces some limitations, such as potential discomfort from extended sessions, these challenges can be mitigated through careful session design and time restrictions. Targeting younger and middle-aged populations, along with plans to extend testing to older individuals, ensures the tool's versatility and applicability across a wide range of people. Further enhancements, such as the addition of navigation tasks and refinements to existing scenarios, will further strengthen the diagnostic capabilities.

In conclusion, the proposed VR game is a promising step forward in leveraging technology to improve healthcare outcomes. By creating an intersection of gamification, VR, and AI, this project sets the stage for new diagnostic tools and provides a model for patient-friendly, non-invasive solutions for Alzheimer's.

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Authors' Contributions

The authors' contributions to the paper are equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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