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Towards a Barrier-free Virtual World and Metaverse: Fairverse

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Abstract

An estimated 1.3 billion people worldwide (roughly 16% of the global population) are affected by various forms of disability. As highlighted by the World Health Organization, many face mobility-related challenges that significantly restrict their ability to participate fully in social and communal life. These restrictions hinder communication and reduce opportunities for linguistic and social enrichment. This study addresses these challenges by proposing Fairverse, an accessible metaverse designed to enhance socialization and inclusivity for people with physical disabilities. Using virtual reality (VR), blockchain and game technologies, Fairverse initially operates as a VR environment but also supports web-based access to ensure broader usability without specialized hardware. As a proof of concept, a customizable virtual room was developed that integrates Ready Player Me avatars and barrier-free avatars that can be controlled by voice commands. To ensure sustainable governance, a Decentralized Autonomous Organization (DAO) is proposed underpinned by a token economy, facilitating sponsorships and donations to incentivize content creators and virtual-world developers. By fostering an inclusive digital ecosystem, Fairverse aims to remove accessibility barriers in the virtual world, empowering users with disabilities to participate fully in the metaverse.

1. Introduction

According to the World Health Organization (WHO) report (https://www.who.int/health-topics/disability), approximately 1.3 billion people (about 16% of the global population) live with some form of disability. Many people experience limited mobility or other physical impairments resulting from medical conditions. Currently, more than 2.5 billion people worldwide require one or more assistive products, such as wheelchairs, prosthetics, or mobility aids. According to the WHO Assistive Technology report (https://www.who.int/news-room/fact-sheets/detail/assistive-technology), this number is projected to rise to 3.5 billion by 2050 with an aging population and the increasing prevalence of noncommunicable diseases. These figures notably exclude those who have not applied for official disability status or government support.

Traditionally, social, public, and individual living spaces have been designed to accommodate the needs of the majority, often resulting in limited accessibility for people with disabilities [1,2]. Moreover, the communication needs of people with disabilities are often unmet, and accessible information remains insufficient. [3,4].

Efforts to improve accessibility have led to innovations such as Microsoft's Xbox Adaptive Controller, designed to enhance the usability of the Windows environment for individuals with physical disabilities [5]. However, this solution still requires manual operation, posing challenges for those with severe mobility impairments.

Simulation and virtual environments [6-9] are frequently employed across various disciplines to facilitate testing and experiential learning in controlled, replicable settings. Recent research has explored the potential of virtual reality (VR) technologies to enhance psychological well-being among individuals with disabilities [10]. Although these studies show that VR can provide movement experiences for people with physical disabilities, they do not explain how such technologies can be effectively integrated into practical solutions.

VR enables users to immerse themselves in virtual worlds and experience lifelike environments.

Individuals can simulate movement using VR headsets and navigate virtual environments through voice commands, joysticks or keyboards, providing accessibility for those with limited mobility or speech impairments. To ensure the sustainability of such virtual environments, blockchain technology is used to incentivize developer contributions. The key characteristics of blockchain (decentralization, immutability, security, and transparency) make it an ideal foundation for a token-based economy that supports long term project viability [11-14]. However, prolonged exposure to virtual environments carries the risk of addiction [15,16]. To mitigate this, gamification techniques are being applied to encourage healthy usage patterns.

This study addresses the following research questions:

1. Can VR and blockchain technologies be combined to create an accessible metaverse that enhances social connectedness and mental well-being for individuals with disabilities?
2. Can we deploy gamification techniques to reduce the risk of addiction in virtual environments?

We propose a system called Fairverse, a novel system that integrates virtual reality, blockchain, and gamification to create an inclusive and sustainable metaverse. The design and implementation of this system are detailed in the following sections.

1.1 Related Works and General Problems

The investigation of physically disabled individuals' physical, mental, and social well being is a prominent research topic [17]. The analysis of research reveals that physical activity avoidance among physically disabled individuals is due to the challenges encountered while participating in activities. As a result of the research, individuals reported reasons such as reluctance to leave home alone, dislike of physical activity, personal health issues, and difficulty finding a physical activity partner. This issue represents the first identified problem. [18-25].

Several studies have examined the potential of the Internet to foster socialization among people with physical disabilities [26]. The findings suggest that employing Internet technologies more efficiently enables social activities among the disabled as opposed to traditional in-person activities. Despite this, feedback indicates that realism may be at risk, necessitating further inquiry. For instance, a recent study investigated [27] how attachment to the Metaverse affects disabled users' acceptance of their disability and their need for uniqueness, influencing their psychological well being. This issue represents the second identified problem.

Several studies have indicated that virtual reality technologies have been utilized to address the realism issue in research involving various disabilities, previously conducted using internet technologies. A study investigating the effectiveness of virtual reality technology on disabled individuals determined the intensity of the sensations experienced [28]. In a separate study utilizing virtual reality technology for disabled individuals, it was discovered that a higher level of immersion in online education positively influenced individuals with disabilities, indicating that a greater sense of reality in online learning could enhance their learning outcomes [29]. This issue constitutes the third identified problem.

Individuals who have temporary physical disabilities and return to social life after treatment often report experiencing problems in social interaction [30,31]. This issue constitutes the fourth identified problem.

Existing studies have not sufficiently addressed the issue of accessibility of individuals with physical disabilities to virtual environments. Accessibility in virtual worlds is mostly evaluated through visual and auditory barriers, while the experiences of individuals with physical disabilities are ignored [32-35]. This creates an important gap in terms of inclusion in emerging digital environments such as the metaverse. For instance, a recent study [36] critically reassessed existing Metaverse concepts and proposed a framework to enhance inclusiveness for physically disabled artists. The study emphasises the active involvement of disabled content creators in the development of Metaverse solutions, highlighting the necessity for standards and regulations to ensure accessibility. This issue constitutes the fifth identified problem.

A comparison of similar initiatives is presented in Table 1. The study offers solutions to the problems detected . While all three platforms support basic VR technology and general accessibility, they differ significantly in motion support and system sustainability. Fairverse offers the most complete features, including voice command motion control and a token economy model, while Embrace VR and Walkin VR are missing some of these advanced capabilities. Eye tracking and brain reading motion support are not yet available on any of the platforms. Expanding this discussion would help clarify how these differences affect user experience and accessibility, as well as the potential advantages and limitations of each platform.

Table 1. Comparison of VR accessibility features across platforms

Feature	Fairverse	Embrace VR	Walkin VR
VR technology	+	+	+
Accessibility	+	+	+
Motion support with eye tracking	-	-	-
Experience of movement	+	+	-
Motion support with voice commands	+	-	-
Motion support with brain reading	-	-	-
Token economy model for system sustainability	+	-	-

2. Method

A virtual world, known as Fairverse, has been developed using virtual reality technology for

individuals with physical disabilities. The system is currently being tested with disabled individuals to prototype its potential. To ensure that the system functions effectively for users who receive voice commands and provide feedback using images and voice, their visual and speech capabilities must be intact. Visually impaired individuals can derive benefits from the system by exploiting its imaging capabilities. The application's usage corresponding to users' disability types are presented in Table 2. This table highlights which users may need expert approval, which users can access the system directly, and which groups may not be supported.

Table 2. Usage and availability of Fairverse by disability categories

Individuals by Disability Types	Application Availability
Mentally disabled	Expert approval is required.
Visually impaired	-
Physical disabilities	+
Hearing impaired	+
Attention deficit and hyperactivity disorder	Expert approval is required.
Language and speech	-

The system model is shown in Figure 1. The model shows the relationships between users, developers, and the DAO (Decentralized Autonomous Organization). The system design illustrates how users can interact with the platform and establish social connections, as well as the roles of developers within the ecosystem and how their contributions will be evaluated. The objective of this approach is to enhance users' interaction and socialization experiences while supporting both the system's usability and long term sustainability. The contents of the system model are explained in detail in the following sections.

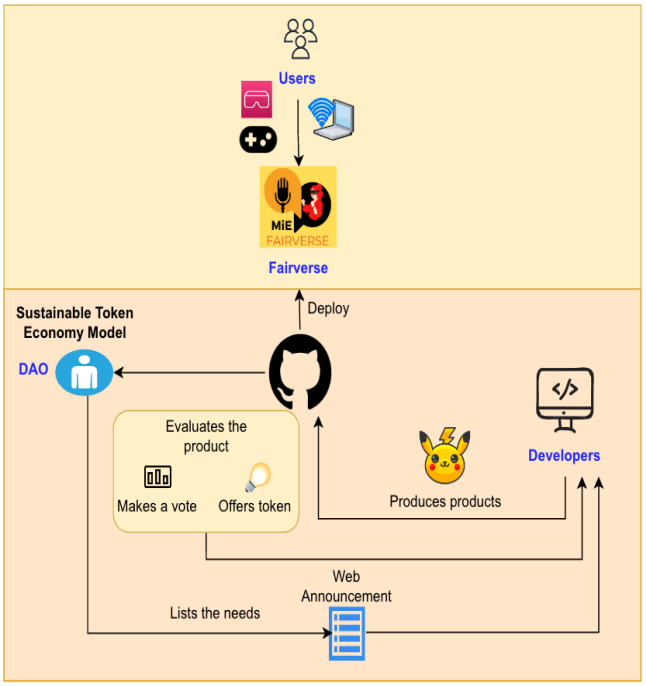

Figure 1. System model

2.1. Usability Features

To access Fairverse, a computer with internet access and virtual reality glasses is necessary. Afterward, the application can be accessed through a web browser. Upon the users' first entry, the menu screen will welcome them and display the commands they may use in the avatar selection screen and virtual environment. Users can manipulate their avatars using voice commands instead of joystick-like products. There are currently instructions for turning right, turning left, moving forward, moving backward, running, waving, dancing, interacting with objects, and opening the menu screen. When the user activates the "Menu" voice command, a selection of available voice commands will be displayed. The user may choose to use any of the available voice commands or switch to using the joystick or keyboard if preferred. Users can interact through voice commands in an entertaining environment featuring pre-existing animations. Individuals can use their avatars unrestricted, viewing their digital character's movement in the virtual room's mirror. Various game activities are available in the virtual environment.

2.2. Sustainability Features - Token Economy and Decentralized Organization Model

The aim is to create an economic model that ensures sustainability by using blockchain technologies for users to store their tokens in their virtual wallets. As a sustainability goal; we want to make this system continue its operation. The creator economy is an important part of it and a basic token economy model is established.

The DAO is at the center of the token economy model. DAO is a decentralized organization, and everyone has equal rights. In a central system, the system is managed hierarchically as the system works according to the decisions made by the manager. However, everyone has equal rights in DAO. In such a system, the rules of Fairverse are predetermined by writing smart contracts. The rules, which are written with smart contracts, are securely stored in the blockchain network and automatically executed by the decentralized system without requiring any human interaction. Nobody can make changes to the structure of smart contracts, as it requires a significant amount of effort to modify the blocks in the blockchain network. Every member of the DAO has equal right to vote when deciding on the requirements of the system and the number of tokens allocated to developers. The running of the Fairverse is determined by a voting scheme in which every member of the DAO has an equal right, with no privileges or advantages.

Tokens called “Fair Token” (FT) are created for the token economy model. FT is used as a reward in the virtual environment. Future plans include finding sponsor companies and converting tokens to reward coupons and product discounts.

The distribution of tokens among different products is decided by the DAO members' vote. A system has been developed to encourage contributions.

Algorithm 1: Algorithm of the DAO System

```
Step 1: DAO Members Create Needs List  needsList ← createEmptyList();
for each member in DAOMembers do
    suggestion ← getInputFromMember(member) ;      /*Get suggestions from the website*/
    addSuggestionToList(needsList, suggestion);
end
Step 2: Needs Announcement to Developers
announceNeedsToDevelopers(needsList) ;      /*DAO members announce the needs on the web*/
Step 3: Developers Produce Products
for each developer in Developers do
    product ← produceProductFromNeedsList(developer, needsList)
    developerAddress ← getDeveloperMetaMaskAddress(developer)
    submitProductToGithub(product, developerAddress)
end
Step 4: Casting Votes by DAO Members
for each member in DAOMembers do
    connectMetaMaskWallet(member) ;            /*Members connect with their accounts*/
    castVote(member) ;                        /*Members decide on the amount of tokens*/
end
Step 5: Determine Voting Results
results ← determineVotingResults() ;                    /*Determine the selected ones*/
Step 6: Deposit Tokens to Winning Developers
winningDevelopers ← getWinningDevelopers(results);
for each developer in winningDevelopers do
    depositTokensToMetaMaskWallet(developer) ;       /*Token deposit to the developers*/
end
```

Algorithm 1. DAO System Algorithm

Sustainability is ensured by managing the process through consensus. Furthermore, the developers also guarantee the sustainability of the system.

Developers play important roles in the system in addition to the target audience. Developers can earn tokens by integrating new objects, animations, and other innovations into virtual environments. Developers can introduce new products to the Fairverse environment.

DAO decides the given amount of the developer prices. The voting process and the inclusion of developers in the system are carried out using an algorithm that includes the following steps as shown in Figure 2. This model is shown in Algorithm 1. This algorithm is of significance as it establishes a transparent, decentralized and democratic mechanism for decision making in Fairverse. The governance process is structured into distinct phases, from the identification of requirements to the compensation of developers. It ensures the equitable allocation of resources, devoid of any central authority or bias.

Step 1: DAO Members Create Needs List

Each member can make suggestions about needs in a particular channel of the DAO. A list of requirements is created with the suggestions of DAO members.

Step 2: Needs Announcement to Developers

The needs lists are shared for everyone to see. The needs lists are announced to the developers on the created website.

Step 3: Developers Produce Products

Developers produce a product on the need list and send it to Fairverse. While sending their products, they also send their MetaMask virtual wallet addresses.

Step 4: Casting Votes by DAO Members

DAO members can view the products submitted by the developers on the website. After connecting with MetaMask virtual wallets, each member casts their votes according to the voting mechanism of the DAO.

Step 5: Determine Voting Results

After the voting is complete, the results are determined according to the voting mechanism of the DAO, and the number of tokens with the most votes is determined.

Step 6: Deposit Tokens to Winning Developers

In the final stage, the specified amount of tokens is deposited into the Metamask virtual wallet, which the developer shares during the product submission phase.

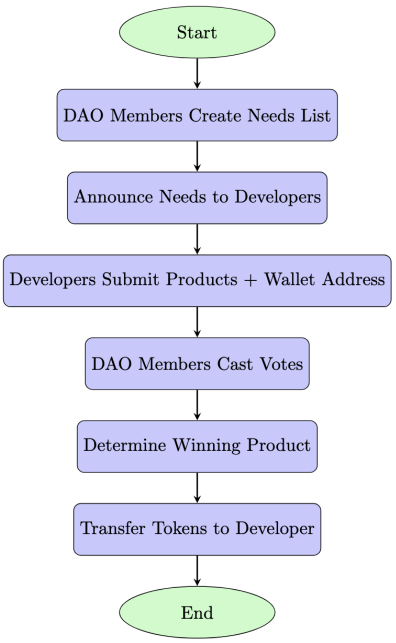

Figure 2. Flowchart of the DAO System

In the token economy model, the main functions are token creation, token burning, token transfer, and learning the token amount of a given address. Token burning aims to control the fair usage of the tokens. Token transfers occur between two valid addresses for the transfer of the specified amount. The number of tokens is decreased from this account after a successful transfer. The token amount of the receiving address is increased with the transferred tokens. The token amount of each address is learned from the balance map. Balances map is a key-value pair; the keys store the address, and the values store the number of tokens owned by that address.

2.3. Socializing Of The User

The system aims to encourage user socialization and expand their vocabulary. The virtual environment includes a social park designed to reduce the social interaction difficulties experienced by individuals who have temporary physical disabilities and have resumed social life after receiving treatment. The purpose of this park is for users to engage in a question and answer activity with avatars to obtain current information. Thus, users acquire new knowledge and up to date information that they can utilize to participate in social activities and conversations. During the question-and-answer session, users approach the avatars and employ the "do" voice command, which triggers random questions. When the questions are answered correctly, tokens are given to the users. If the wrong answer is given, the correct answer to the question is explained to the user by voice.

2.4. Gamification Sustainability

To prevent virtual environment users from becoming dependent on the environment, the task "Getting away from the Screen" was designed and added to the menu section. The purpose of these tasks is to prevent users from becoming dependent on the virtual environment. Users receive rewards according to the time they enter the virtual environment. The rewards that users earn according to the time they enter the environment are shown in Algorithm 2. Algorithm 2 ensures that users remain engaged with the application and develop healthy usage habits. For instance, users who spend between 30 and 50 minutes daily in the environment receive 2 FT, those who spend between 50 and 60 minutes receive 1 FT, and no rewards are given for usage beyond 60 minutes. This configuration is designed to curtail protracted periods of screen time, whilst advocating frequent and regulated engagement with the application. The flowchart of the gamification system is shown in Figure 3.

3. Implementation

As a prototype, a virtual environment has been created. This environment is incorporated into the web, enabling users to access it from any location. Its objective is to offer immersive experiences that disabled users can participate in and enjoy. Users can access these experiences through voice commands or a joystick. The system features a token economic model to ensure long-term sustainability. Technologies known as Web 3.0 are employed. Details of the implementation are explained in the relevant subheadings within a virtual realm and decentralized Web 3.0 environment.

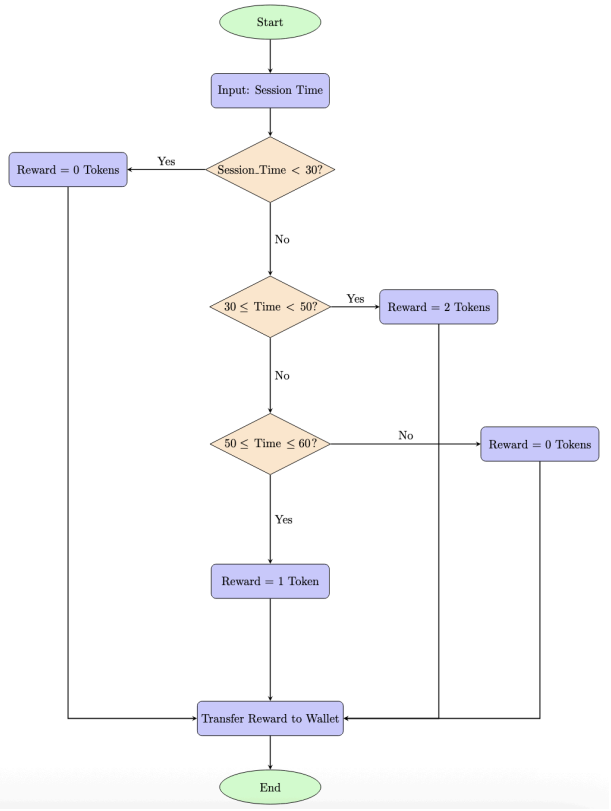

Figure 3. Flowchart of the Gamification System

Algorithm 2: Algorithm of Gamification

```
Data: dailyUsage (minute type), taskOneCounter, taskTwoCounter, dayCounter
Result: Tokens earned through gamification
taskOneCounter ← 0;
taskTwoCounter ← 0;
dayCounter ← 1;
while dayCounter < 30 do
    switch dailyUsage do
        case 30 ≤ dailyUsage < 50 do
            giveToken(2) ;                          /*Task 1:  My Eyes Are Resting*/
            taskOneCounter ← taskOneCounter + 1;
        end
        case 50 ≤ dailyUsage < 60 do
            giveToken(1) ;                              /*Task 2:  Oh Effort*/
            taskTwoCounter ← taskTwoCounter + 1;
        end
    end
    switch taskOneCounter do
        case 7 do
            giveToken(3) ;                               /*Task 3:  I'm Fit*/
        end
        case 15 do
            giveToken(5) ;                      /*Task 4:  My Eyes Are Like Eagles*/
        end
        case 30 do
            giveToken(50) ;                         /*Task 5:  Conscious User*/
        end
    end
    switch taskTwoCounter do
        case 7 do
            giveToken(2) ;                          /*Task 6:  I Seem To See*/
        end
        case 15 do
            giveToken(4) ;                             /*Task 7:  I'm In Too*/
        end
    end
    dayCounter ← dayCounter + 1;
    if dayCounter == 30 then
        taskOneCounter ← 0;
        taskTwoCounter ← 0;
    end
end
```

Algorithm 2. Gamification Algorithm

3.1. Virtual World

A prototype of a virtual world environment is created with the Unity game engine to produce lifelike places and objects in the metaverse universe [37]. Initially, a virtual room and garden are fashioned using the Blender application to design the three dimensional features [38]. The scenario begins in the user's room, where they can freely express themselves. A virtual mirror is integrated into the entrance of the virtual room, allowing individuals to view themselves without hindrance and simulate movement as shown in Figure 4. The system includes multiple virtual worlds, with a sample garden featuring a swing and trampoline as shown in Figure 5. This project aimed to provide individuals with physical disabilities, who have not had the opportunity to experience swinging on a swing or jumping on a trampoline, with a similar sensation. The Social Park, which utilizes the Unity game engine, has been designed to achieve this. Figure 6 displays the Social Park along with a sample question. Examples of the questions presented in this environment include topics such as the construction date of the first aircraft, the dates of significant historical events, or recent developments in science and technology. These questions are intended not only to provide knowledge but also to stimulate conversation, helping users to engage more effectively in social interactions.

Avatars are created with the Ready Player Me web service and integrated into the virtual environment [39]. Selected Ready Player Me avatars are built in.

Pre-created avatars are offered to users so that they will not bother designing their avatars. The user can also optionally use his/her avatar in the virtual environment. User can move their avatars through voice commands. Voice commands are developed with C# programming language. Windows Speech Recognition library is used and integrated into the virtual environment.

3.2. Decentralized Web 3.0 Environment

The token economy model and related codes for decentralized structure developed. A token economy model has been studied to ensure the sustainability of the system. The tokens that users can obtain as a result of various activities integrate into the virtual environment. ERC-20 token as the project will be voting with virtual money standard used.

Users can securely store their tokens within virtual wallets provided by Metamask. The development of rules involves the creation of smart contracts that are written in Solidity, a programming language. The coding process utilizes the Remix editor. Transactions are recorded on an academic blockchain network built on Quorum, a permissioned version of Ethereum where smart contracts automatically enforce rules. Quorum [40] is an institutional solution and academic network that users can access for free, with no accompanying gas fees. It distinguishes itself from other blockchain platforms by its low energy consumption. In support of the system, a contract named 'TokenId.sol' has been established following ERC-20 standards. The contract allows developers on the platform to utilize a voting system. As per the voting outcome, the creator of the digital universe is granted a token for their created object. This contract acts as a centralized component of the blockchain system, incorporating various features such as token transfer, token burning, token balance reception for a specific address, and details about the token's name, symbol, and total supply. These functionalities are crucial for the proper operation of the system. The contract follows the Openzeppelin library's ERC-20 token creation standard.

Figure 4. A Virtual Mirror Where Users See Themselves

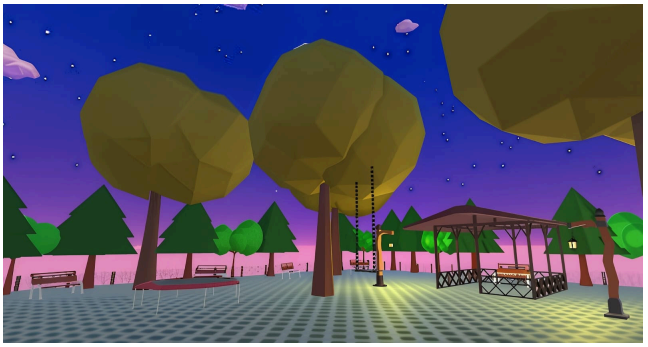

Figure 5. A Virtual Garden With Swings and Trampoline

Figure 6. Sample Question From The Social Park

In addition to the token contract, a governance mechanism has been implemented through the DAOVote smart contract. This contract enables decentralized voting within the virtual environment. Users can cast votes in one of four predefined categories (Silver, Gold, Diamond, or Platinum) each representing different attributes or levels of virtual content or contribution. The contract includes functions for voting, retrieving vote counts, and resetting the results, all of which are executed transparently on the blockchain. Only the designated manager, typically the contract deployer, is authorized to finalize and clear the voting rounds. Additionally, the findMax() function is used to determine the most voted category, allowing the system to dynamically identify user preferences or winning proposals.

The voting mechanism is supported by the ERC-20 compatible token contract named MiEToken, which was developed using the OpenZeppelin library. This token contract defines the digital asset "Fair Token" with the symbol "MiE" and a total supply of one million tokens, minted at deployment. The contract includes extended features such as token burning and customizable decimal precision, set to two for ease of use in micro-transactions. This token acts not only as a unit of value but also as a tool for user engagement and contribution tracking within the metaverse platform. By integrating both smart contracts, the system enables a cohesive and transparent structure where participation, reward, and decision-making processes are fully decentralized and verifiable.

When creating a token, a name, and symbol (MiE) are determined for our token. The total number of

tokens is specified as one million when deploying the smart contract. JavaScript programming language used when creating a website. The user interface of the website is written in the React software language. React software language bootstrap library is used for the user interface. The token economy model and virtual environment website are integrated.

4. Results

Before using Ready Player Me avatars, we wanted to use the avatars we created through the MetaHuman Creator [41]. Although the avatars created through MetaHuman Creator were better in terms of resolution, they were causing late loading and stuttering. That is why we chose Ready Player Me avatars for user-friendliness. The Quixel Bridge program was used to integrate MetaHuman avatars into Unity and test them. The avatars created on the website through the program called Bridge can integrate MetaHuman avatars into Unreal Engine [42]. Avatars can be exported and integrated with Unreal Engine to Unity. A C# coded script was employed to measure the loading time of avatars. The results revealed that avatars created through Ready Player Me loaded within 0.004-0.005 seconds, whereas avatars produced through MetaHuman Creator loaded within 0.008-0.010 seconds. The analysis indicates that the avatars created through Ready Player Me were twice as fast as those created through MetaHuman Creator.

Additionally, the performance of different VR headsets was evaluated in hardware tests. Oculus Quest 2 glasses were used while testing the developed system. However, we found that using Oculus Quest Rift and HTC Vive rather than Oculus Quest 2 is more efficient. Oculus Rift and HTC Vive ushered in a new era of consumer-oriented VR, and subsequent years have seen a proliferation of head-mounted displays available to consumers [43].

The system was tested by users and received generally positive feedback. Participants reacted with expressions of surprise and joy, such as “wow”, “oh my god”, expressing their satisfaction during the experience. There was no negative feedback during the test process, especially no feedback expressing fear or discomfort. The trampoline and swing elements in the virtual park were particularly emphasized by the users. The participants emphasized the realism of the experience offered by these elements and stated that they strongly experienced the feeling of jumping on the trampoline and physically swinging on the swing.

4.1. User Test Findings and Interpretation

This section analyzes qualitative data from the first user test of the Fairverse prototype and examines the user experience under the headings of accessibility, emotional impact and technical competence. This pilot study included a small number of participants and provides an initial look at the user experience. The results are indicative and should be interpreted with caution due to the limited sample size. Information on the test design, including how questions were asked, how responses were recorded, and the reliability of observations, is provided to give context to the findings. Plans for a large scale evaluation are in place to further validate these results. The study is based on observations and semi-structured interviews with five participants of different ages and abilities.

Three of the five participants in the test group were between the ages of 18-30 and two were between the ages of 31-45. Two participants were physically disabled (mobility impairment), one was visually impaired and two were non-disabled (control group). This distribution was chosen to represent different access needs in line with the inclusion goals of the Fairverse platform.

Question 1: Users’ Navigation Experience How intuitive was the navigation (e.g. voice commands, menu interactions) in Fairverse?

Four out of five participants reported that navigation was “very easy” or “somewhat easy”. The ease of use of voice commands and menu interactions was particularly emphasized. However, participants sometimes reported delays of 2-3 seconds in responding to voice commands. One participant rated the navigation as “neutral”, suggesting that user experience with some aspects of the system may vary depending on individual differences.

Question 2: Responsiveness and Accuracy of Voice Commands: How responsive and accurate were the voice commands?

Two of the participants stated that the voice commands worked “always correctly”, while the other two participants evaluated them as “mostly correct”. One participant stated that the voice commands “sometimes did not work”. When the open-ended responses were analyzed, it was observed that the commands lost their functionality especially in noisy environments or system-related delays.

Question 3: Barriers and Accessibility Issues: Have you encountered any obstacles while using Fairverse? If yes, please explain.

Two participants reported various access issues. One participant with a physical disability stated that the lack of audio description during the avatar selection process caused difficulty in orientation. Another user reported problems with orientation due to the slow response time of voice commands.

Question 4: Emotional Responses: What emotions did you experience during the Fairverse experience?

Three participants reported intense feelings of “joy” and “freedom”. In particular, a physically disabled user stated, “I felt like I was swinging for the first time in years”. However, one participant reported feeling “frustrated” due to technical problems with the hardware installation.

Question 5: Technical Issues: Have you encountered technical problems?

Two participants reported delays in loading avatars. One user also reported that voice commands did not work in noisy environments. Requests for higher resolution textures were expressed.

5. Discussion

The project's possible psychological effects on users have been discussed with our academic advisors in the psychological guidance section. Based on the feedback and recommendations, work has been done on improving the psychological effects of the system on individuals. Distraction tasks have been added to prevent users from becoming addicted to the application.

Although the application was not specifically developed for individuals with cognitive or learning disabilities, it is anticipated that these individuals can also use it. However, if individuals use the application, depending on the type and severity of their disability, there may be both positive and negative effects. To minimize this risk, discussions are being held with academic experts and specialists in this field. It is recommended that individuals use the application with the approval of a specialist. Some users, especially those with cognitive or learning disabilities, may require alternative control mechanisms or additional training to use the system effectively.

The Oculus Quest 2 headsets used in the study are devices that can work effectively on their own. However, when connected to a computer with a cable, the Quest 2 worked below its capacity. This sometimes caused the image to freeze. As a result, the performance of the Oculus Quest Rift and HTC Vive, which are designed to work with a cable, can be preferred as they have better performance than Oculus Quest 2. Additionally, the cost and availability of VR hardware, as well as the system's sensitivity to voice commands and environmental noise, may affect users' ability to access and fully benefit from the application.

Several technical and practical factors can affect the accessibility and usability of the application. The cost and availability of VR hardware, the system's sensitivity to voice commands, and environmental noise can influence users' ability to access and fully use the application. Poor internet connections or low performance computers may also limit the user experience. Creating more detailed environments and avatars to make the system more realistic can further reduce performance and increase load times.

Financial constraints should also be taken into account. Although VR equipment is becoming more affordable, it is still costly, especially in less developed regions. Development costs for integrating VR technology, blockchain features, and setting up a DAO structure remain high. Therefore, obtaining enough users and sponsor support is crucial for the project's long term success.

These factors, including hardware requirements, system sensitivity, and the need for user adaptation, may be considered when evaluating the practical feasibility and broader accessibility of Fairverse.

6. Limitations of the Study

As the Fairverse project develops, several constraints must be taken into account. We will cover the technical, user, and financial constraints in the appropriate subsections.

6.1 Technical Constraints

Our implementation has a hardware requirement. VR gear is needed to offer a virtual reality experience. However, not everyone has access to this equipment. Furthermore, poor internet connectivity and computers might have a detrimental effect on the user experience.

The system needs a quiet environment for voice recognition to work as expected. In noisy settings or with users' accents or speech problems, the system's accuracy may be compromised. The user experience may be limited as a result.

For more realistic implementation, more detailed and realistic environments can be created; however, these will have an effect on the performance of the system. As an example, using more detailed avatars could make the system run slower, and these will result with longer load times.

6.2 User Constraints

Accessibility can be a constraint for some users. Some disabled people may not be able to use voice commands due to physical or cognitive difficulties. For these users, the incorporation of alternative control mechanisms (such as brainwave-based control) might be required.

Even though we have worked to make the environment as user-friendly as possible, people with disabilities may need some time to get used to technology. Users may need to receive training to become proficient in virtual worlds.

6.3 Financial Constraints

The price of VR equipment is becoming more affordable but still expensive, especially for underdeveloped countries. However, Fairverse also supports web-based access to ensure broader usability without specialized hardware. Also, development costs are still high. Using VR technology, integrating blockchain, and establishing a DAO structure may all come with hefty development costs. The requirement for more resources can increase as a result. Getting enough users and sponsor backing is essential for the project's long-term viability.

7. Conclusion

The proof of concept of the proposed system showed that it is possible to provide movement experiences to people with physical disabilities through virtual environments. The project source code is shared through a GitHub repository and the application is also accessible through the project's web page. Making the application freely available through web browsers will significantly increase accessibility.

The proposed token economy model is successfully implemented. Developers will be able to contribute to the virtual environment by earning tokens in exchange for creating digital products. This will lead to the

continuous development of new content and ensure its sustainability as new content will ensure users enjoy the environment without getting bored. The system will sustain itself through a DAO model. Wallet support and digital assets are also tested with the system. Users will be able to store the digital assets they earn in personal wallets, utilize them within the virtual world, or trade them. This will not only increase user engagement but also support the development of the virtual economy. We are aware of ongoing legal developments regarding cryptocurrencies, and global progress in regulatory frameworks is being closely monitored. For instance, after the Hatay earthquake, the Turkish NGO Ahbap accepted cryptocurrency donations, proving that such models are feasible within the country. These kinds of cryptocurrency supported contributions have the potential to attract asset creators and developers.

Fairverse has been demonstrated at various events and competitions. During these events, individuals with physical disabilities used the working demo and received positive feedback. The project was successfully implemented and received several awards.

In future studies, several enhancements are planned to further expand and develop the virtual environment. One objective is to create portals leading to different virtual universes, offering users diverse experiences. This incorporation aims to enhance user engagement and interaction within the virtual environment. Integration of artificial intelligence applications is also planned to increase internal development activity. Multi-user support can be added to enable users to socialize and interact with others in the virtual world. Movement support through thought using EEG (Electroencephalography) devices can also be added. The main limitation of the study is the dataset. To achieve more precise and reliable results, the data set must be rich. To this end, both the data we collect ourselves and the open datasets shared similar to recent works [44,45] in previous studies are being used. This approach is important for broadening the scope of the analyzes and increasing the validity of the results. The data from these devices can be converted into digital signals, and a dataset can be created by matching them with physical movements. This data can be used to build a system where users can move their avatars in the virtual environment simply by thinking. Thought based motion control will serve as a practical solution in scenarios where voice commands are insufficient.

Overall, this pilot study provides preliminary insights into the Fairverse user experience, highlighting both strengths and areas needing improvement. A larger scale user evaluation is planned to future works and validate these findings and to strengthen the generalizability of the results.

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Author Contributions

All authors participated in preparing the manuscript. R.D. did the implementation work and experimental procedures. R.D. conducted the analyses and contributed to drafting the results. R.D. and E.K. led the primary writing of the manuscript and provided scientific insights that shaped the development of the article. All authors approved this final published version of the manuscript.

Conflicts of Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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