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Preliminary Development of Vircadia Virtual Reality Platform for Monitoring Water Quality Powered by Solar Panels

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***Abstract*—Climate change is a global issue that significantly challenges water resources, especially in regions with limited public awareness about water conservation. It manifests through rising global temperatures, shifting weather patterns, more frequent and intense natural disasters, and instability in water availability. Low public awareness and reliance on steam power plants for water pumps worsen these problems. Addressing these challenges requires educational media that raises awareness about the causes and impacts of climate change. This study introduces the early development of a Virtual Reality (VR) platform utilizing Vircadia, focused on creating a 3D world and monitoring water quality with the support of solar power. Vircadia, an open-source platform, offers developers the flexibility to build and host virtual worlds on their servers, providing greater control over the environment, scalability, and customization. With Vircadia, we can rapidly implement a VR platform that integrates custom assets from Blender and personalized avatars from Ready Player Me. Vircadia can seamlessly connect to IoT platforms via Weblink, allowing real-time monitoring of water quality parameters and enabling users to interact directly with and oversee IoT devices within the VR environment. This paper discusses why we chose Ready Player Me and Blender as platforms for building 3D avatars and assets and Vircadia as the VR Platform. Additionally, it addresses challenges encountered when using Vircadia, such as asset optimization and IoT device integration. Future research will focus on optimizing asset quality, enhancing IoT integration, and implementing carbon emissions monitoring within the VR platform.**

***Keywords*— 3D asset; 3D avatar; vircadia; VR platform; water quality.**

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I. Introduction

Climate change represents a growing and intricate global issue, impacting multiple facets of human life and the environment [1]. The main issue is the increase in greenhouse gas emissions, particularly carbon dioxide and methane, which predominantly stem from human activities like fossil fuel combustion, deforestation, and unsustainable farming practices [2], [3], [4]. The buildup of these gases in the atmosphere leads to the greenhouse effect, where solar heat is retained on Earth. It is projected that this could cause the global average temperature to increase by as much as 5.4°C by the year 2100 [5]. The effects of climate change are evident around the globe, manifesting as increased average temperatures, more frequent and intense extreme weather events, rising sea levels, and damage to ecosystems that endanger the survival of several species [6], [7], [8], [9].

Climate change presents a significant challenge for Indonesia, especially regarding water resources [10]. It causes extreme weather changes, increased temperatures, and unpredictable rainfall patterns, directly affecting water availability [11], [12]. The general need for more public awareness about the importance of water conservation exacerbates this issue.[13]. Key factors contributing to this issue include insufficient public awareness and understanding

of the importance of environmental cleanliness and effective water management [14]. Furthermore, the reliance on Steam Power Plants (PLTUs) for powering water pumps is a concern, as these plants are significant sources of air pollution [15]. Emissions from PLTUs can deteriorate air quality and raise temperatures, potentially posing risks to human health [16], [17].

To address this issue, an effective medium is needed to enhance public awareness and knowledge about climate change in Indonesia. One potential platform is Virtual Reality (VR) technology. For example, research by Zixiang et al. [18] discusses the development of a VR platform to raise young people's awareness about rising sea levels. The study indicates that VR platforms can effectively increase awareness and serve as an educational tool on climate change issues.

To address this issue, we developed a VR platform supported by solar power to monitor water quality. This platform was created using Vircadia, an open-source metaverse that enables developers to build and host their virtual worlds on their servers [19]. Unlike platforms such as VRChat, which require developers to use VRChat's servers for their worlds, Vircadia allows for greater flexibility. In this VR platform, we also designed 3D avatars to represent users and 3D assets to construct a realistic virtual environment. Additionally, the platform features real-time water quality monitoring using Internet of Things (IoT) devices.

Several studies discuss climate change integrated with Virtual Reality as a medium for raising users' awareness. Galeote et al. [20] conducted research focused on developing a game application using Unity to enhance understanding and interest in the future impacts of climate change. The study produced an educational 3D virtual reality game, but it was only tested on a small number of users, which may limit the generalizability of the findings.

Hassan et al. [21] developed problem-based learning (PBL) in remote learning scenarios that offer climate change Virtual Reality (VR) to train students' critical thinking skills. This PBL is in the form of a mobile application and runs on smartphones. The application is intended for high school students and teachers in a controlled educational environment.

Adjanin et al. [22] developed Virtual Reality 360-degree video technology (VR-360) that provides users with an experience that resembles real life and includes engaging storytelling. User testing conducted by the authors revealed that VR-360 on climate change offers educational benefits, specifically for learning about global climate change.

Asita et al. [23] developed Immersive Virtual Learning (IVL) to enhance understanding and cognitive skills related to climate change issues. This research addresses the challenge of understanding climate change material, which is complex and requires good thinking skills. IVL was tested with middle school students, who found that IVL provided a different impact and understanding than traditional classroom learning. IVL includes a Virtual Field Trip (VFT) featuring educational videos on climate change, focusing on its causes and effects.

From the related works mentioned above, we created a comparison table with the Vircadia VR platform, using various categories and features, as shown in Table I. This paper presents the development process of the Vircadia VR platform to monitor water quality that receives power from a solar panel. This preliminary publication will focus on developing technical parts and discussing the obstacles to using Vircadia.

TABLE I
COMPARISON OF RELATED WORKS

Category	[20]	[21]	[22]	[23]	**Vircadia VR Platform**
Educational Environment	✓	✓	✓	✓	✓
Cross-Platform Accessibility	X	X	X	X	✓
Immersive Interaction	✓	X	X	✓	✓
Real-Time IoT Data Integration	X	X	X	X	✓
Integration with VR/3D World	✓	X	✓	✓	✓
Custom Avatar	X	X	X	X	✓

II. MATERIALS AND METHOD

This section discusses the method used in the Vircadia VR platform, as shown in Fig. 1.

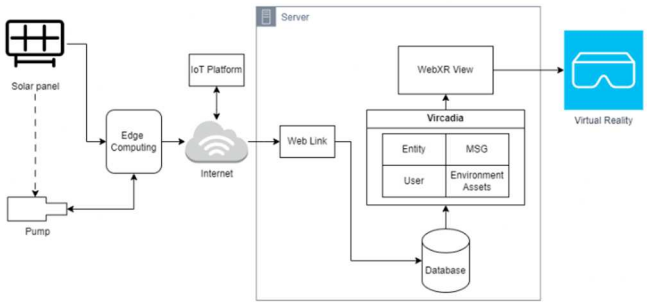


Fig. 1 System Design for Vircadia VR Platform for Monitoring Water Quality Powered by Solar Panels

A. 3D Avatar

The development of the Vircadia VR platform began with asset creation, specifically 3D avatars and 3D assets. The 3D avatars are user agents during travel or navigation within the Vircadia VR Platform. The avatars are created using the Ready Player Me platform [24]. The Ready Player Me platform is web-based, with various character templates ready to use [25]. It also allows you to create your characters according to your needs, with templates for clothing and other avatar body specifics such as hairstyle, body shape, and skin color [26]. The avatar design is divided into male and female categories, with each gender having a specific set of clothing, as shown in Fig. 2. Image (a) depicts a 3D avatar of the male gender, and image (b) depicts the female gender. The development of two distinct gender-specific avatars allows users to select 3D avatars that align with their gender preferences [27].

(a) (b)

Fig. 2 3D Avatar. (a) 3D male avatar, (b) 3D female avatar

The 3D avatar model is downloaded, and the file format is converted in Blender [28] from glb to fbx and unpacked textures and materials, as shown in Fig. 3. Modifications are necessary to meet the requirements for the file format to be imported into Vircadia.

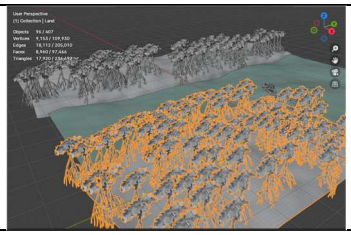
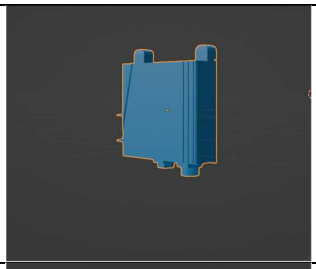
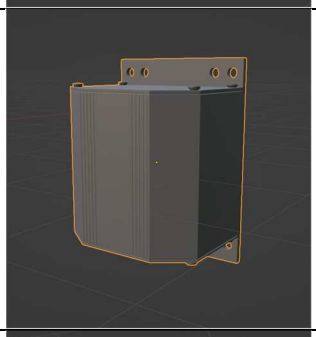
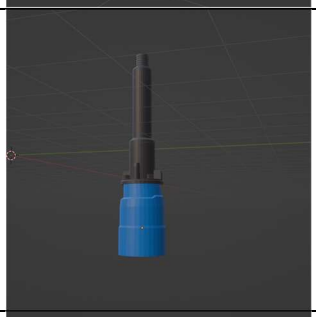
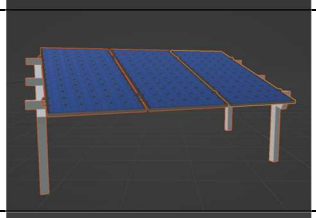
Fig. 3 File Conversion and Unpacking Textures and Materials Process

B. 3D Asset

The next step involves incorporating 3D assets into the VR Platform to create a more immersive experience for users on the Vircadia VR Platform. The theme of this asset is a green environment featuring a water pump and solar panels as IoT equipment, representing their real-world counterparts. These assets include 3D models of environmental elements and IoT equipment used for monitoring water quality. 3D asset development using Blender 3D. Table II shows the 3D assets that have been created.

The assets "Mangrove River," "Mangrove River Ecotourism Wonorejo," and "Mangrove Tree" are used as environmental elements inputted into the 3D world, while 3D assets such as "Water Pump Controller," "Lorentz," and "Solar Panel" are used as digital twin representations of the IoT devices we have built in the real world. These assets were created using Blender, along with additional assets obtained from open-source 3D asset websites.

TABLE II
3D ASSET

No.	Object's Name	3D Asset
1.	Mangrove River Ecotourism Wonorejo, Surabaya	
2.	Water Pump Controller	
3.	Lorentz Communication	
4.	Water Pump	
5.	Solar Panel	
6.	Mangrove	

C. VR Platform

The development of the VR Platform in this research utilizes Vircadia, a platform for creating a VR world or metaverse that can be installed on your server. The development of the VR platform in this research utilizes Vircadia, a platform for creating a VR world or metaverse that can be installed on your server. This allows for greater control over the environment, scalability, and customization. Unlike proprietary platforms, Vircadia's open-source nature allows developers to modify and enhance the platform according to specific needs, making it a versatile choice for projects requiring tailored solutions. Additionally, it supports the integration of various 3D assets and IoT devices, enabling the

creation of realistic digital twins and interactive experiences within the virtual environment [29]. Fig. 4 shows the default view of the 3D world in Vircadia. By default, the world is empty and contains nothing.

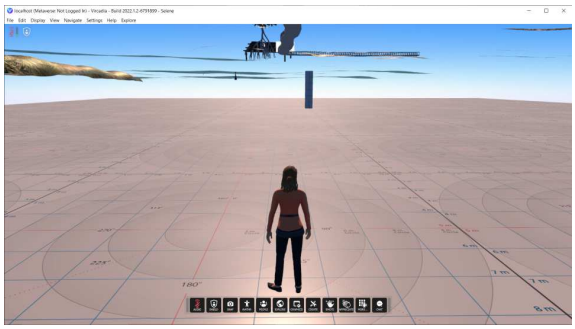


Fig. 4 Vircadia VR Platform Interface

D. Adding Assets to the VR Platform

3D avatars and 3D assets are added to the Vircadia VR Platform using the Create tool, which allows for importing 3D assets in OBJ, FBX, and JSON formats. This tool provides flexibility in asset management, enabling developers to bring a wide range of models and avatars into the virtual environment. The Create tool also supports customization and optimization of these assets within the platform, allowing for seamless integration and interaction in the 3D world. This capability enhances the immersive experience by ensuring that the virtual environment is populated with high-quality, interactive elements that align with the project's objectives. Fig. 5 displays the 3D avatar in Vircadia.

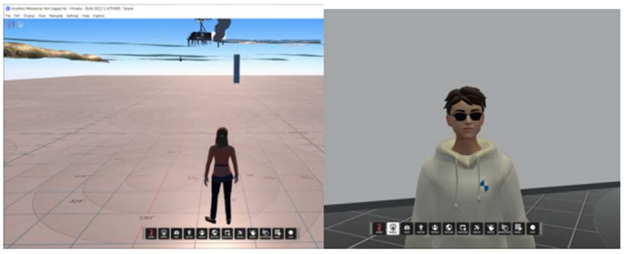


Fig. 5 3D Avatar in Vircadia

Fig. 6 shows the view of the 3D environment assets added to the VR Platform. Image (a) displays the Wonorejo Mangrove River with added 3D mangrove trees, and Image (b) shows the solar panel added to the 3D asset of the Wonorejo Mangrove River. Users can interact and navigate within the 3D world.

(a) (b)

Fig. 6 3D Environment Assets in the VR Platform. (a) 3D asset of Wonorejo River, (b) 3D asset of Solar Panel

E. Entity

Entity Vircadia is a web link used to integrate the IoT Platform into the VR Platform. The IoT platform is used for real-time monitoring of IoT devices within the 3D world of the VR Platform. The IoT platform is used for real-time monitoring of IoT devices within the 3D world of the VR Platform. This monitoring system is integrated with real-world IoT devices, including DHT11, CC811, PZEM017, and Flowrate sensors. The data being monitored includes temperature, humidity, water volume, electricity usage, and carbon emission detection. The development of real-time IoT monitoring requires a web link that will be displayed on the VR Platform. Fig. 7 shows the real-time IoT monitoring interface in the Vircadia VR Platform.

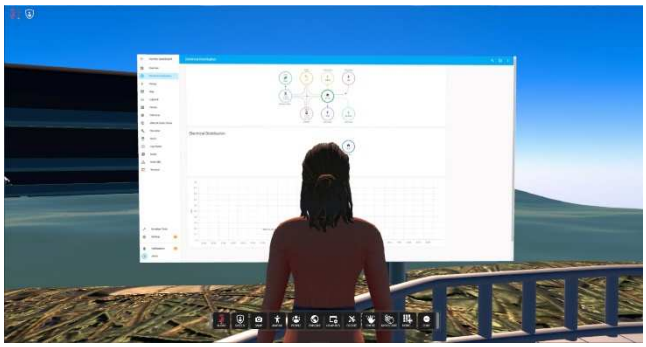


Fig. 7 Real-Time IoT Monitoring in Vircadia on the VR Platform

III. Result and Discussions

A. The benefits of Ready Player Me and Blender for asset development

We use the Ready Player Me platform to create 3D avatars because of its features and benefits, including:

1) Customization: Users can design unique avatars with extensive personalization options, including facial features, hairstyles, clothing, and accessories.

2) Interoperability: Avatars created with Ready Player Me can be used across various platforms and virtual worlds, ensuring a consistent identity. Ready Player Me is compatible with a broad range of environments, including virtual reality, augmented reality, and web-based experiences.

3) Integration Ease: Ready Player Me offers APIs and SDKs that simplify the integration process into existing games and applications. Developers can tailor the integration to meet their specific needs and requirements. One of the examples is to integrate the 3D avatar into Vircadia VR Platform.

4) Time and Cost Savings: Developers can save time and money by avoiding the need to create their own avatar system from scratch. The platform manages many of the technical challenges involved in avatar creation, such as rigging, animation, and optimization.

In addition to the Ready Player Me platform, MakeHuman is another platform for creating 3D avatars. There are differences in why we chose to use Ready Player Me over

MakeHuman [30] in the development of the Vircadia VR Platform, as shown in Table III.

From the comparison in Table III, it can be concluded that the Ready Player Me platform offers greater flexibility to 3D avatar developers compared to using MakeHuman. This is because Ready Player Me has cross-platform features, allowing developers to quickly export 3D avatars into VR, AR, and web-based applications, whereas MakeHuman requires manual export to other applications.

TABLE III
THE COMPARISON BETWEEN READY PLAYER ME & MAKEHUMAN

Comparison	Ready Player Me	MakeHuman
Platform	Web-based, without installation	Desktop app, requires installation
Cross-Platform	Avatar can be use across various environment (VR, AR, and web-based app)	Avatar must be exported manually for use in other applications
Accessibility	Support Multiple Platforms (Windows, Linux, macOS)	Support Windows and Oculus Devices
Customization	Limited but easy-to-use	Start with base human model with extensive customizations

In this research, we also used the Blender platform for converting 3D avatar files and creating 3D assets such as world environments and 3D objects. We use Bender because it offers several features and benefits, including:

1) Accessibility: Blender is freely available, making it accessible to users regardless of budget.

2) Community-Driven Development: Blender is open-source software continuously evolving through contributions and innovations from a large, active community.

3) Support and Resources: Users benefit from an extensive and active community offering support, tutorials, and various resources.

4) Add-ons: Enhance Blender's capabilities with a wide range of community-developed add-ons.

B. The benefits of Vircadia as a VR platform

Using Vircadia as a VR Platform provides advantages and features that make it easier to use than other VR platforms. These benefits include:

1) License Model: Vircadia's open-source license (Apache 2.0) allows free customization, distribution, and collaboration, offering flexibility, transparency, and cost-effectiveness in VR development.

2) Large Groups / Scalability: Vircadia's virtual worlds are designed to accommodate large groups, supporting hundreds of participants within the same environment without requiring instancing.

3) Custom Avatar: Users can easily customize their avatars in real-time, with support for various styles. Additionally, avatars provided by Ready Player Me can be integrated seamlessly.

4) Creation Capabilities: Vircadia offers expansive virtual worlds, with up to 4096 km³ of buildable space. All construction and scripting occur in real-time, facilitating rapid, efficient, and collaborative development.

5) Cross-Platform Accessibiliy: Vircadia worlds are accessible across multiple platforms, including Windows, Linux, macOS, and mobile devices via web access.

6) FLOSS+ Decentralized: Vircadia is a decentralized platform, accessible from Windows, Linux, and macOS. Future updates will extend support to Android, iOS, and Quest 2.

In addition to the benefits of Vircadia as a VR platform, in terms of 3D world development, Vircadia has several advantages over VRChat [31], which is another VR platform for building 3D worlds. The differences in features are shown in Table IV.

TABLE IV
THE COMPARISON BETWEEN VIRCADIA & VRCHAT

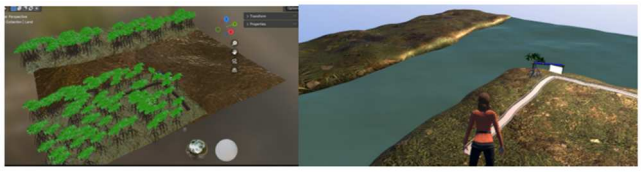
Comparison	Vircadia	VRChat
License Model	Open- Source	Proprietary
Scalability	On premise & Cloud; Depend on own server's resources	Only Cloud, Depend on the cloud resources
Custom Avatar	Supports Custom Avatars via Various 3D Formats (OBJ, FBX, JSON)	Supports Custom Avatars with Unity and SDK
Creation Capabilities	Up to 4096 km^3	Limited by instance size and performance constraints, typically smaller
Accessibility	Support Multiple Platforms (Windows, Linux, macOS, Android)	Support Windows and Oculus Devices
Decentralization	Decentralized Platform	Centralized Platform.
Open Web-Access	Yes	No

From Table II, it can be concluded that Vircadia offers more convenience and flexibility for developers because it is an open-source platform compared to VRChat, which is proprietary (owned by a specific person, company, or organization) and does not allow the installation of 3D worlds on private servers.

C. Challenges in Using Vircadia

Alongside the benefits offered by Vircadia, we faced some challenges in developing the VR Platform. These include:

1) World Creation Optimizing: Optimizing applications created within Vircadia can be challenging, reducing the quality of the imported assets. An example of inadequate optimization is shown in Fig. 8. In image (a); the environment contains many trees. However, as depicted in the image (b), when the asset is imported into Vircadia, the number of trees in the environment is reduced.



(a) (b)

Fig. 8 The Challenge of World Creation Optimization in the Vircadia VR Platform. (a) A 3D environment with a large number of trees, and (b) the condition of the 3D environment asset after being imported into Vircadia.

2) Integration IoT device: Vircadia allows for the integration of IoT devices within a 3D world. The IoT devices are connected to the IoT platform, which is then displayed on the Vircadia VR Platform via a web link. The challenge of this research is integrating IoT devices with the IoT platform, which must subsequently be monitored within the VR Platform.

IV. Conclusion

This preliminary paper discusses the development of a VR platform using Vircadia to monitor water quality powered by solar panels. We developed a 3D world VR platform using Vircadia, incorporating features and benefits such as scalability for large groups, custom avatars, and cross-platform accessibility. The 3D avatars were created using Ready Player Me and Blender, serving as user agents within the 3D world of the Vircadia VR platform. Additionally, 3D assets such as the Wonorejo river environment, solar panels, and water pumps were integrated into the VR platform to create a virtual world that offers users a realistic experience. Vircadia, an open-source platform, allows developers to create and host virtual worlds on their servers, offering enhanced control over the environment, scalability, and customization. With Vircadia, we can quickly establish a VR platform that incorporates custom assets from Blender and personalized avatars from Ready Player Me. It also supports seamless integration with IoT platforms through a weblink, enabling real-time monitoring of water quality parameters and allowing users to interact with and manage IoT devices directly within the VR environment. The future work outlined in this preliminary publication involves implementing the monitoring and calculation of carbon emissions within the Vircadia VR Platform.

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