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Gamelan Land: A Multiplayer Virtual Reality Game based on a Social Presence Approach

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***Abstract*—A Multiplayer Virtual Reality Game (MVRG) was developed in order to support experiences in learning and playing orchestral music through a virtual world called the Gamelan Land (GL) game. The GL game was aimed as a virtual place to support interaction between musicians and Gamelan enthusiasts who are spread all over the world. It supports them carrying out Gamelan community activities in the real world into a virtual world through immersive virtual experiences. The story developed in the GL game reflects the real life of the Gamelan community. Oculus Quest 2 which is a Head Mounted Displays (HMD) device that can deliver highly immersive 3D environments was selected as the platform to run the Gamelan music MVRG provided in the GL game. The performance of the Gamelan music MVRG shows promising results. Improvement of audio and visual latency in playing music in orchestra is still a problem to be solved. The problem can be caused by differences in internet network speed and device specifications. So far, low poly 3D models can be an alternative solution. Moreover, although it still requires testing involving more users and longer time, the social presence approach in the GL game can be implemented well and has promising prospects for further development.**

Keywords—Virtual reality musical instrument, multiplayer virtual reality game, social presence approach, metaverse, Gamelan

I. INTRODUCTION

Metaverse provides multisensory interactions involving virtual environments, digital objects, and humans [1], as well as exciting new forms of telepresence [2], and has the potential to change people's everyday lifestyles [3]. Metaverse is suitable as a medium for gathering people who have similar interests with the support of immersive experience sensations even though their presence is spread throughout the world. The recognition of Gamelan as a world cultural heritage is a motivation to utilize the metaverse as a solution to bring together gamelan communities spread throughout the world. Gamelan, a traditional Javanese musical ensemble, has become a world property and is officially listed as a UNESCO Intangible Cultural Heritage. The existence of Gamelan communities is not only limited to Java or Indonesia, but is spread throughout the world, such as the United States which has almost 200 Gamelan communities spread across all its states [4], England which has almost 160 Gamelan groups [5], the Padhang Moncar Gamelan Group from New Zealand, and others.

A system of learning and playing Gamelan music in orchestral mode which can be accessed by the public simultaneously without limitations of place and time was proposed in this study. In existing similar works, systems for learning to play Gamelan music developed by [6-7] has not implemented immersive learning that can bring users into a virtual environment. Virtual Reality (VR) can be used for immersive simulation by imitating the real or imagined world through a desktop screen or HMD, and HMD is a device that provides high immersive display quality [8]. Meanwhile, metaverse is a synthetic environment hypothetically related to the physical world [9] that offers immersive experiences and integrates various new technologies that are closely related to VR [10].

The challenge in this research is to build a virtual world that can support users from all over the world to carry out activities like gamelan communities in the real world, and provide an immersive experience. Therefore, the research carried out since the end of 2022 focuses on two main works to answer research questions which are the development of an MVRG for Gamelan music learning and playing, and the development of a virtual Gamelan world called the GL game using social presence approach. Furthermore, the MVRG was added in the GL game. The GL game is projected to be developed on the metaverse platform, so the game design must contain metaverse characteristics, such as realistic information that reflects the real world [11].

The GL game aims to be a medium for gathering musicians, enthusiasts, researchers from all over the world to socialize, such as making music, discussing or carrying out other Gamelan activities virtually like in the real world. Gamelan studio membership in the real world which is usually based on location proximity can be expanded through the GL game. Furthermore, the gamelan studio management system applied in the real world is analyzed to formulate the rules of the GL game. The system is designed based on the characteristics of Gamelan studios which refer to the building, a set of musical instruments, and the characteristics of individuals who act as owners, managers, teachers, members (musicians and singers), visitors and clients. Virtual world presentation regarding audio and visual quality is also a challenge in developing the GL game. Higher resolution presentations provide better viewing including smooth viewing in real-time. Changing the direction of view is a challenge in developing virtual worlds [12], such as that faced in the GL game development. However, due to limited resources, not all game designs were carried out in experiments. Experiments used only a part of them that was considered as a basis for future development. Details of the game design and elements selected for the experiments are described in the Methodology section.

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II. Related Works

Virtual Reality Music Instruments (VRMIs) is a research topic that utilizes VR technology to convert musical instruments into 3D object formats. The principles in the development of VRMIs formulated by [13] include a mapping between sound, visual, touch, and body position and movement (proprioception), minimum tolerance for delays in data transfer (latency) in visualization and sound, design inspiration but not replication based on real instruments to develop existing possibilities by utilizing technological support, and a sensation creation of the user's presence in interacting with the instrument and in a 3D environment. In the teaching-learning relationship, there is a special tendency to apply VR technology for immersive learning with the aim of getting a better visualization process [14]. Immersion is an important factor in successful learning, and an immersive learning environment can bring users directly into various experiences and events related to learning content [15].

HMD technology development that can support rendering of complex textured scenes and scenes in real-time has prompted the development of VR-based digital musical instrument research [16]. Implementation of immersive learning in musical instruments is carried out by [17-19] using HMD Virtual Reality (VR) as a simulator. Video signal processing to visualize the scene into HMD is very burdensome for the Central Processing Unit, and latency is a requirement for hardware processing of the system [20]. Drum instruments transformed into VRMIs by [18] allow users to interact with the system via physical hands and drums by implementing an infrared sensor-based camera connected to Oculus Rift HMD. Oculus Quest which is a standalone HMD is more flexible than Oculus Rift [19]. One of the advantages of stand-alone HMDs is the support for freedom of movement for users because they do not require a computer with a cable connection to run applications.

Gamelan instruments have been transformed into VRMIs in a single-player game format by [21]. A multiplayer game format can be applied in order to support orchestral music characteristics. A multiplayer game can be created based on the physical location of the user in the same place or in the different places connected via the Internet. Online multiplayer games support an unlimited number of users, including collaboration games between users who do not know each other [22]. Compared to non-VR, VR-based multiplayer games improve user experience in almost all aspects, such as immersion, competence, positive impact, challenge, and behavior [23]. Existing research on the topic of VRMIs is still rarely implemented in orchestral or ensemble music mode. The methodology proposed in this study extends the VRMIs model into the Virtual Reality Orchestra Music Instruments (VROMIs) model by implementing them into a MVRG. Algorithms development and User Interface/User Experience (UI/UX) design that allow more than one user to interact in the virtual world of music are challenges in this study.

A survey conducted by [24] on documents related to metaverse research published from 1990-2021 showed it culminated around the time of a press conference by Mark Zuckerberg containing his desire to make metaverse a reality. Metaverse research in various fields and topics is growing and varied, and one of them is in the field of music. Metaverse has grown beyond VR by integrating cutting-edge technologies such as 5G, cloud computing, computer vision, blockchain, artificial intelligence, and others [10, 25], and has developed across a wide range of applications for gaming, education, arts, business and more. Continuous research to apply VR technologies such as metaverse is needed to support future learning experiences [25].

As the implementation of the social presence sensation, there are positive benefits that can be obtained from metaverse. For example, a mirror world in gamification in order to deliver non-game content in the real world through game design [26], the evolution of online games that have a thin difference between virtuality and reality [27], unlimited accessibility was a factor in choosing the metaverse as a platform to deliver educational content [28], or solutions to social communication problems as in a metaverse-based application developed to improve the social skills of children with autism spectrum disorder [29]. These benefits are in accordance with the development of a virtual world in the metaverse which contains cultural heritage preservation content that is also educational, such as the GL game developed in this research. In addition to the physical presence that gives the sensation of 'being there' (being in the virtual world), simulation approach that allows users to interact or communicate with each other is an important element in the development of the virtual world in the metaverse where this experience affects the internal emotions and external environment perceived by users [30]. Moreover, elements of avatars, stories and multi-users can improve the quality of the experience [31].

The core of future metaverse applications can be grouped into virtual social, virtual medical, virtual city or virtual games [32]. Preservation of cultural heritage is one of the topics that can be implemented in the metaverse application, either in the type of virtual social, virtual city, or virtual games, or a combination of these types, such as the GL game which was developed more into a virtual social type that contains educational and preservation of cultural heritage contents. However, a wide bandwidth network connection is one of the elements needed to carry out mass activities in metaverse [33]. This is certainly a challenge in bringing together the masses in the virtual world who are physically located in different countries or regions, while some of them have a significant different bandwidth network connection speed. The characteristics of this problem are also a challenge in the development of the GL.

III. Methodology

The development of the virtual Gamelan world was carried out in two main stages, namely the development of the MVRG, and the development of the GL game. The method consists of five stages, namely data collection, 3D modeling, game design, game programming, and evaluation.

A. Data Collection

Observation and interview techniques were used to collect data. This stage produces output in the form of graphic designs of Gamelan instruments and their environments, as well as audio data assets from each instrument, and Gamelan

community activity data summarized from interviews with experts. All the collected data was then used as a reference to formulate game rules.

Gamelan music consists of two musical scale systems with different audio signal frequencies, which is the *pelog* musical scale system that consists of seven notes of 1, 2, 3, 4, 5, 6, 7, and the *slendro* musical scale system that consists of five notes of 1, 2, 3, 5, 6. A Gamelan set consists of instruments that are grouped into three categories, which are melodic skeleton, melody and structural [34]. Instruments in the melodic skeleton group play melodic skeleton notation, such as *demung, saron, peking, slenthem, bonang barung,* and *bonang penerus*. Instruments in the melody group play melody notation, such as *gender, siter, rebab* (a bowed instrument), and *suling* (bamboo flute). Instruments in the structural group play notations that determine the form of the song, such as *kendang* (drums), *kempul, gong, kenong, kethuk, kempyang*.

There are rules in the layout of the instruments. Observations were made to get visual data of Gamelan instruments and its layout. Furthermore, measurements and photo documentation were carried out on each Gamelan instrument to be used as references in transforming real objects into 3D models, as well as photo documentation of Gamelan instruments layouts. Data were collected in the Pangreksa Budaya Gamelan Studio located in Semarang city, Central Java, as shown in Fig. 1.

Fig. 1. GAMELAN SET LAYOUT ILLUSTRATION PICTURE TAKEN FROM THE PANGREKSA BUDAYA GAMELAN STUDIO

Audio data were also collected in the same gamelan studio. Audio data of each pitched instrument was recorded per instrument key, then the recording results were saved in wav format. The naming of audio data was performed using a format of *the musical scale system-instrument-key instrument*, in which the key instrument containing notes data. For example, pelog_demung_1.wav, pelog_demung_2.wav, and so on, until pelog demung 7.wav. The *kendang* instrument (Javanese: Percussion) which is played by tapping the hand has a variety of tapping techniques that produce a variety of sounds. However, only basic variations of sound were used in experiments. The *kendang* instrument consists of three types divided based on their size, which are large, medium and small *kendangs*. The basic techniques in playing percussion using right and left hands were recorded. The recording of the basic right hand stroke technique on large, medium and small *kendang* were stored and labelled with the names kdr-big.wav, kdr-medium.wav and kdr-smal.wav, respectively, where kdr is obtained from kd which is abbreviated from *kendang* and r is an abbreviation of the word right. Meanwhile, the recording of the basic left hand stroke technique on large, medium and small *kendang* were stored and labelled with the names kdl-big.wav, kdl-medium.wav and kdl-smal.wav, respectively, where kdl is obtained from kd which is abbreviated from *kendang* and l is an abbreviation of the word left.

Gamelan community activity data collected by interviewing Gamelan experts is used to formulate game rules. Game rules utilize game design elements, such as points, badges, leader boards, performance graphs, meaningful stories, avatars, and teammates, to create activities in non-game contexts [31]. Game design elements used in the experiment were limited to points, performance graphs, avatars, story, and teammates. All Gamelan communities are connected to Gamelan studios, so activities in Gamelan studios become the basis for formulating game rules. Game rules were defined using a case-study design research where finding phenomena in real-life context is used as the unit analysis [35]. Furthermore, the analysis unit for determining game rules was focused on the management of Gamelan studios in carrying out training, and collecting points by users.

Gamelan studios are spread across various regions, from sub-district, city, provincial and state levels. In fact, in Central Java, Indonesia, there is more than one Gamelan group in one sub-district, and Gamelan studio membership is usually based on location proximity. The organizational structure of a Gamelan studio consists of owners, managers, instructors, musicians and singers. Outside the Gamelan studio there are the roles of visitors and clients. Visitors are people who visit Gamelan studios with various background interests, such as studying, researching, or just watching gamelan studio members do practice. Clients are people or representatives of an institution who invites a Gamelan group to perform at an event they are holding. A Gamelan studio holds performances based on client requests at special events, such as weddings, birthday parties, holiday celebrations, and others. Only wealthy clients can invite a Gamelan studio to perform. Large funds are needed to provide and maintain Gamelan studio buildings, Gamelan musical instruments and other supporting assets, including paying members' salaries. Therefore, not everyone except those who are financially capable can own a Gamelan studio. In general, Gamelan studios are owned by well-known musicians, or Gamelan enthusiasts who invest their funds to build Gamelan studios as a form of expression or contribution to the preservation of Gamelan.

Land and buildings are requirements to build a Gamelan studio. The price of a Gamelan studio building is influenced by its location. The design of the GL game environment refers to the atmosphere of traditional Javanese society, where buildings are made of wood, and characteristic Javanese carvings on buildings are symbols of social class. Most Gamelan studios have two sets of musical instruments, one each for the *pelog* and *slendro* musical scale systems. The total number of instruments in each Gamelan studio ranges from 30-60 instruments, even more. Most Gamelan musical instruments are percussion instruments made of iron, brass or

bronze, and played using wooden mallets. The price of a set of gamelan musical instruments varies, depending on the materials used, including wood and decorations on the musical instruments (carvings). Gamelan instruments made of bronze are the most expensive, followed by brass, then iron. In the experiment, differences in the quality of musical instruments and wood carvings including land location were not used in determining the price of building a Gamelan studio in the GL game.

Well-known Gamelan studios will receive many invitations to perform. The cost of inviting a Gamelan group depends on its level of popularity. Therefore, the existence of a Gamelan studio depends on the quality of its members, namely the skill or fame of the owner or manager, the skill of the musicians in playing the Gamelan, and the melodiousness of the singers. Recruitment of gamelan studio members can be done through regeneration, talent search, individuals registering to join, or through members inviting acquaintances to join. The GL game removes location restrictions for becoming a member of a Gamelan studio. Thus, membership in Gamelan studio is not exclusive and is not limited to proximity to location. Musicians who are renowned for their skills or famous singers from one Gamelan studio are often asked to help other Gamelan studios perform.

B. 3D Modeling

The next stage is 3D modeling which results output in the form of 3D models for instruments, environments and their properties that are used for game assets. Traditional 3D modeling techniques were chosen to transform real Gamelan instruments into 3D objects because of their flexibility in controlling the number of vertices and polygons for modeling 3D objects.

Low-poly 3D models were targeted for reducing rendering costs in order to reduce latency risk. Usually, there are Javanese carving motifs on the body of Gamelan instruments. The carving motif was not included in the 3D model to maintain the low-poly 3D model results. 3Ds Max application program was used for the 3D modeling process. Fig. 2 shows an illustration of 3D modeling results for Gamelan instruments.

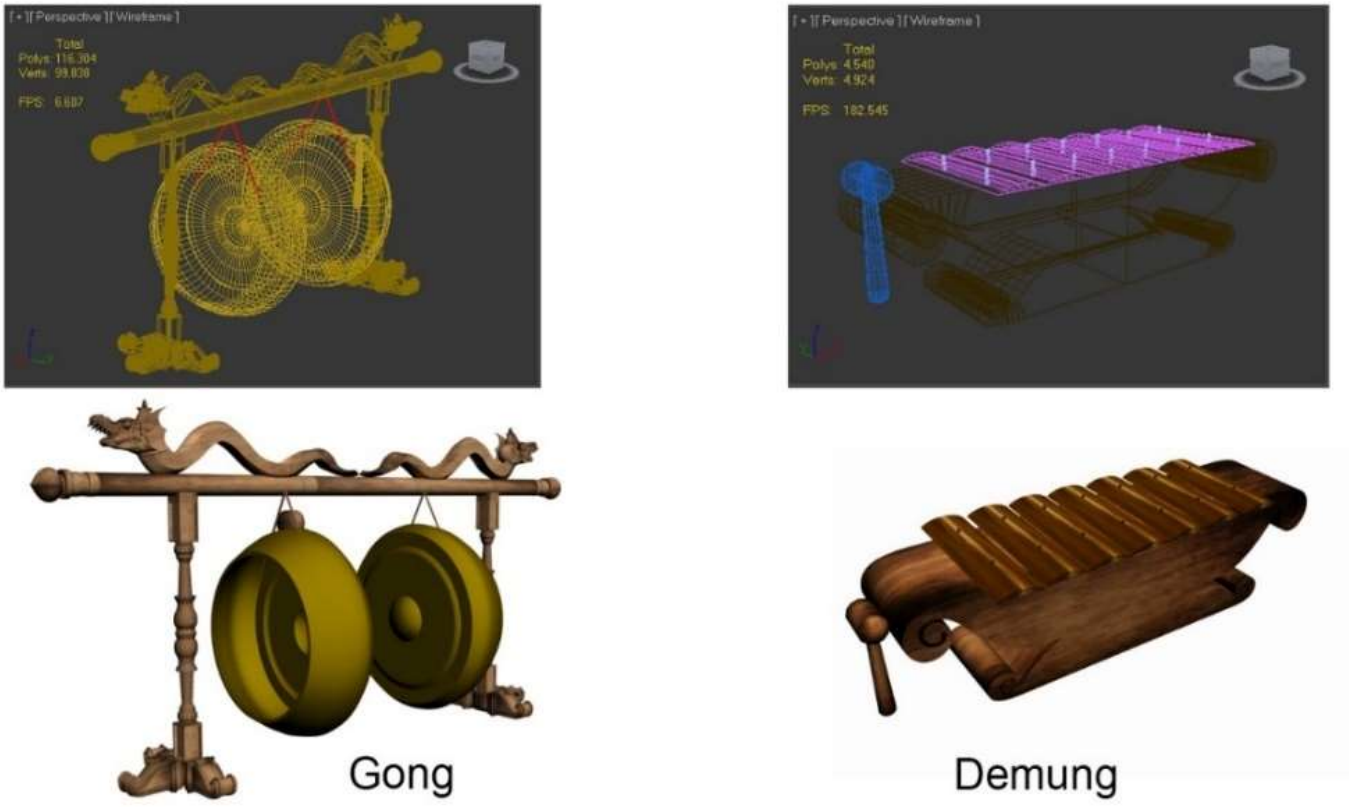

Fig. 2. EXAMPLES OF 3D MODELING RESULTS FOR THE INSTRUMENTS OF *GONG* (LEFT) AND *DEMUNG* (RIGHT)

C. Game Design

The GL game which includes a gamelan MVRG was developed with limitation on the *pelog* musical scale system data, and the instruments selected were those included in the melodic skeleton and structural groups. Due to the complexity and technique of playing, musical instruments included in the melody group are not used. For example, *gender* which is a pitched metallophone instrument, *siter* which is a stringed instrument and played like harps but in a horizontal position, *suling* (bamboo flute), and *rebab* which is a bowed instrument. It needs further research to transform them to be used in an MVRG.

The stories developed for the GL game reflects the activities of the Gamelan community. A Gamelan studio owner has the task to maintain the existence of his group by recruiting quality human resources, having a Gamelan studio with quality Gamelan buildings and instruments. A manager has the task of advancing the Gamelan studio by recruiting

quality musicians and singers. A manager and owner of a Gamelan studio has the task of building the Gamelan studio reputation by getting lots of invitations to performances. Performance invitations have an impact on Gamelan studio income and can be used for operational costs, paying members, and improving the studio's facilities and infrastructure. An instructor has the task of training musicians and singers to play and perform well. A musician and a singer have tasks that tend to be internal to themselves, which are improving the quality of playing for musicians and singing quality for singers. The quality of their skills has an impact on the popularity of their name, and the Gamelan studio they join.

Visitors and clients are indicators of the existence of a Gamelan studio. The number of visitors is a parameter to measure the quality of a Gamelan studio, while the number of clients is a parameter to measure the income of a Gamelan studio. In this experiment, actors were limited to the instructor, musician, singer and audience as seen in Fig 3. The story was built around the activity of collecting points. The roles of owners and managers are performed by the system, and their tasks are simplified to scheduling practice and paying studio members.

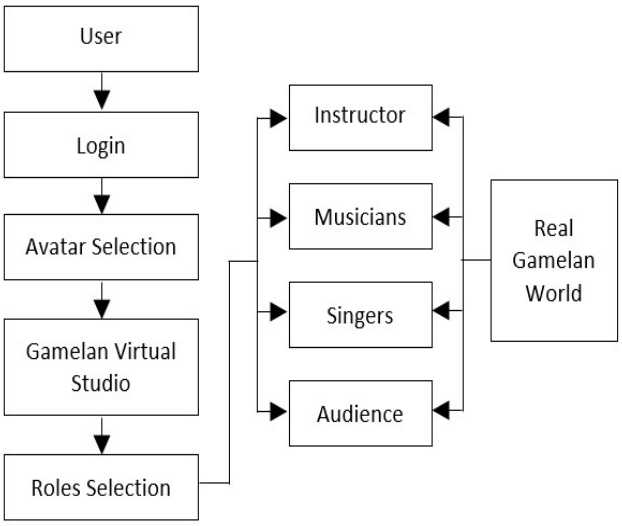

Fig. 3. THE MVRG OF GAMELAN MUSIC MODEL DIAGRAM

Actors are paid using points called *Kreweng*, a Javanese term which means a fraction of a roof. *Kreweng* is used in traditional market children's games involving the roles of seller and buyer, and it functions as a transaction tool in buying and selling games. In the GL game, *Kreweng* points are collected based on a weighted score which is measured based on the user's presence or duration in the game, user activeness in exploring the game, popularity and recognition of skills in playing Gamelan musical instruments for musicians or sweetness. voice for singers.

The weighting formula in the collection of points was determined as K = D + V + P + S, where K represents *Krewengs*, D represents user's presence or duration in the GL game measured using seconds unit with one second is equal to one *Kreweng* point, V represents activity in exploring the GL game measured based on visits to Gamelan studios with the first visit to a Gamelan studio equal to one *Kreweng* point, P represents popularity measured based on the number of thumbs up from other users with one thumbs up from one user equals one *Kreweng* point, and S represents expertise recognition measured based on the number of ratings on a scale of 1-5 obtained from other users with the total rating value of one user being the number of *Kreweng* obtained. Furthermore, based on the interview with Gamelan experts, there are salary levels for gamelan studio members, and the formula determined are instructor salary = K + (D/2); singer salary = K + (D/4); musician salary = K + (D/6).

D. Game Programming

The game programming stage was to build interactivity between users and users with the instrument. The GL game navigation consists of a splash screen page, login, avatar selection and a virtual Gamelan studio. The splash screen displays an animation of the institution logo that develop this study. Next is the login page which gives the user the option to login with the user name or anonymously. After that, the user enters the avatar selection page which provides a choice of 3D characters in a male or female 3D model. Then the user can enter the virtual Gamelan studio.

The GL game was developed to be played using the HMD-Oculus Quest. The system development was carried out using the Unity 3D game engine, while the assets used were 3D modeled using the 3Ds Max program. Meanwhile, multi-user functionality was built using Photon Unity Networking (PUN), a Unity package for multiplayer games, and the database is managed using Firebase from Google.

Fig. 4. SCREENSHOTS OF THE MVRG OF GAMELAN MUSIC, AVATAR SELECTION PAGE (TOP) AND VIRTUAL GAMELAN STUDIO (BOTTOM)

The GL game, which are a reflection of Gamelan community activities in the real world, were developed with limited actors and activities. The actors used are instructors, musicians, singers and audience. Meanwhile, the activities are limited to practice activities to collect points called Kreweng.

The evaluation results will be used as a basis for future development. Figure 4 shows a screenshot of the GL game.

E. Evaluations

Evaluations were performed by involving 14 users to play the GL game including the MVRG. Users were divided based on the roles of instructor, musician, singer, and audience. 10 students who are active in Gamelan extracurricular activities were selected to play Gamelan music, where 9 of them acted as musicians, and another person acted as a singer. A Gamelan practitioner was selected to act as the instructor, three lecturers with Visual Communication Design competencies background were selected to act as the audience. Moreover, evaluation was separately conducted to measure the MVRG and the GL game performances.

First evaluation was to measure the performance of the MVRG. The evaluation was carried out to measure the visual suitability of the 3D model with real objects, sound and visual latency, synchronization suitability between real hand movements, virtual hand movements and instrument sounds, as well as cyber sickness in using the HMD. The evaluation was carried out in four sessions with a duration of 30 minutes for each session. Each user was separated in different rooms located in two different buildings. This was to simulate the existence of users who are physically spread across different locations, and they meet in a virtual Gamelan studio. To record real-time activities of all users in the real world, user activities were documented and recorded in video format using Zoom, an on-line video conference application program. Meanwhile, user activities in the virtual Gamelan studio were recorded by adding a virtual camera feature in the MVRG of Gamelan music whose position and movement were controlled by an operator. Fig. 5 shows a screen capture from a Zoom video showing musical activities in the MVRG.

Fig. 5. SCREEN CAPTURE FROM A ZOOM VIDEO CONFERENCE SHOWING MUSICAL ACTIVITES IN THE MVRG OF GAMELAN MUSIC

Evaluation of the visual suitability of 3D models in MVRG to real objects was performed by asking two questions, which are “do the proportions of the 3D model of the instrument match the original size”? and “is the layout of the instrument set in accordance with the original”? Respondents were asked to give the answer Yes or No. The results showed that all respondents stated that the proportions of the 3D model instruments and the layout of the instrument set were considered to be in accordance with the real world.

The next evaluation was to measure audio and visual latency on the MVRG. Mean Opinion Score (MOS) technique used to subjectively assess image quality as in [36] and audio quality as in [37] was used to measure audio and visual latency in music and communication. The evaluation was performed by giving four statements of “there is no audio latency when I play the instrument in orchestra mode”, “there is no visual latency when I play the instrument in orchestra mode”, “there is no audio latency when I communicate with other users”, and “there is no visual latency when I communicate with other users”. Respondents were asked to determine a value from a range 1-5 which represents strongly disagree to strongly agree, then the results were calculated using the following formula:

$$\mathrm{MOS} = \frac{\sum_{n=1}^{N} R_n}{N}$$

where R are the individual ratings for a given stimulus by N subjects. MOS score results were classified into very bad or there is a very annoying latency for scores that below 3.1, bad or there is latency so it's annoying for scores in the range value of 3.1 - 3.6, common or there is latency so it's a little annoying for scores in the range value of 3.6-4.03, good or there is latency but not annoying for scores in the range value of 4.03-4.34, very good or no latency at all for scores that over 4.34. The MOS score results for the evaluation of audio and visual latency can be seen in Table I.

TABLE I. MOS SCORES RESULTS IN AUDIO AND VISUAL LATENCY EVALUATION

Social Presence Experiences	Latency	MOS Scores	Quality
Playing Music in Orchestra Mode	No Audio Latency	3.72	Common
	No Visual Latency	3.69	Common
Communicating with other users	No Audio Latency	4.14	Good
	No Visual Latency	4.06	Good

The next evaluation was to measure synchronization suitability between real hand movements, virtual hand movements and instrument sounds. The evaluation was performed by giving a statement of “the synchronization between real hand movements, virtual hand movements and instrument sounds is difficult”. Nine respondents who acted as musicians were asked to determine a value from a range 1-5 which represents strongly disagree to strongly agree. The evaluation was carried out in two sessions, where respondents played five songs in orchestra in each session. Table II shows the evaluation results.

TABLE II. EVALUATION RESULTS OF SYNCHRONIZATION BETWEEN REAL HAND MOVEMENTS, VIRTUAL HAND MOVEMENTS AND INSTRUMENT SOUNDS

Activities	1	2	3	4	5
5 times the first sesion	0	0	0	4	5
5 times the second session	0	3	4	2	0

The last evaluation of MVRG was to measure the level of cyber sickness. The evaluation performed based on the use of interior and exterior backgrounds was carried out separately, and each was played for a duration of 15 minutes. Respondents were asked to play a game with an interior background, after which they were asked to rate the statement of “I feel no cyber sickness when I was in the interior background”. Next, respondents were asked to play a game

with an exterior background, after which they were asked to rate the statement of "I feel no cyber sickness when I was in the exterior background". 14 respondents were asked to determine a value from a range 1-5 which represents strongly disagree to strongly agree. Table III shows the evaluation results.

TABLE III. EVALUATION RESULTS OF THE LEVEL OF CYBER SICKNESS USING INTERIOR AND EXTERIOR BACKGROUND

Background	1	2	3	4	5
Interior	0	0	2	5	7
Exterior	0	0	8	6	0

The next evaluation was to measure the GL game performance based on respondent activity in collecting points. The evaluation was carried out by lending VR equipment to each respondent for 10 days. Point collection rules are determined based on activities while in the GL game, which are length of time in GL (D), number of visits to Gamelan studios (V), popularity among users (P), and skill in playing Gamelan (S). Time to join the GL game was scheduled by the systems. However, respondents were allowed to communicate with each other to arrange additional meeting schedules. The training schedule was determined for 10 days with a duration of one hour (3,600 seconds) each day. So, with a duration of 10 days, the expected total time respondents are in the GL game is 36,000 seconds.

The evaluation results show that the shortest total duration of a user's stay in the GL game in 10 days is 4,392 seconds by a musician respondent, and the longest is 29,988 seconds by the instructor. The three users who acted as audience are ranked 4th, 7th, and 11th with a duration of being in the GL game for 22,932 seconds, 18,432 seconds and 7.812 seconds respectively. Meanwhile, the average user stay time in the GL game at every login is 949.8 seconds. Fig. 6 shows a graph containing information about the length of time the user has been in the GL game for 10 days.

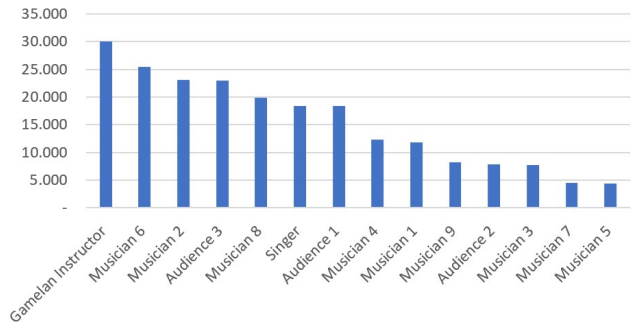

Fig. 6. THE LENGTH OF TIME THE USER WERE IN THE GL GAME FOR 10 DAYS

There are 10 Gamelan studios provided in the GL game that can be accessed by users. Data show that 12 out of 14 respondents visited all 10 available Gamelan studios, while the other two respondents who were musician respondents visited eight and three Gamelan studios respectively. All musical activities were carried out in the main Gamelan studio in accordance with the practice schedule determined by the system, and no additional practice initiated by the respondent. User behavior based on visiting activities at Gamelan studios (V) cannot be concluded with certainty. This is because the roles of owner and manager who have the task of bringing members and visitors to their studio has not been functionalized in the experiment.

User popularity (P) is measured based on the number of thumbs up received from other users. With 14 respondents, it is possible for each user to get a maximum of 13 thumbs up. However, only the instructor got 13 thumbs up. In the real world, Gamelan instructors generally have high popularity, and it can be assumed that this also applies to the GL game.

User behavior in giving thumbs up to other users is more likely to be influenced by the length of duration the user is in the GL game. Based on the results, a user's duration (D) in the GL Game is directly proportional to the number of the thumb up (P), except for musician 5 and audience 3. It can be shown in Fig. 7 which shows the data of duration (D) and popularity (P) graphs.

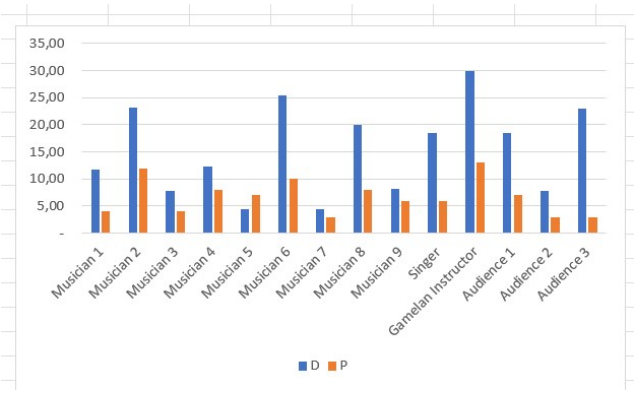

Fig. 7. DATA OF DURATION (D) AND POPULARITY (P).

Skill recognition (S) is to measure the performance of the instructor, musician and singer based on the number of ratings on a scale of 1-5 earned from other users. With 14 respondents, it is possible for those roles to get a maximum of 65 points. Only one user got 65 points which is the Gamelan instructor. The facts found in the skill recognition are similar to those found in the popularity component, where the Gamelan instructors generally have good musical skills. The way users assess skills tends to be directly proportional to the length of duration a user was in the GL game. The initial conclusion shows that the longer user play music on the GL game, the more skilled the user will be. Fig. 8 shows the data of duration (D) and skill recognition (S) graphs based on the roles of Gamelan instructor, musician and singer.

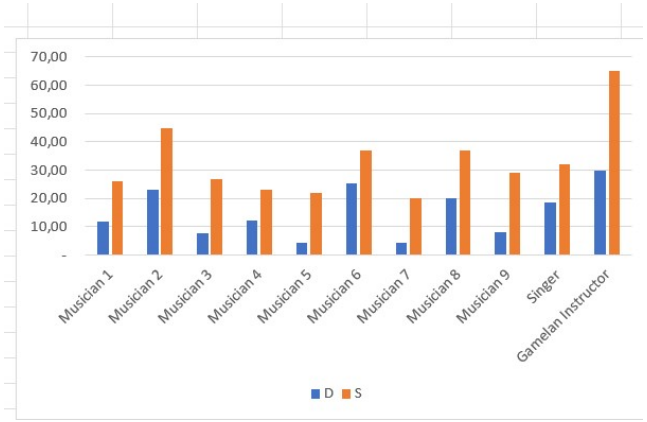

Fig. 8. DATA OF DURATION (D) AND SKILL RECOGNITION (S)

In 10 days of simulation time, the highest point was 30,076 *Krewengs* by the Gamelan instructor who also had the longest duration in GL, and the lowest point was 4,431 *Krewengs* by Musician 5 who also had the shortest duration in GL. Only instructors, musicians and singers receive salaries according to the formulas described in the Game Design section. Thus, the total income of them increased. Based on the salary, the highest point was 45,070 *Krewengs* by the Gamelan instructor, and the lowest point was 5,163 *Krewengs* by the Musician 5. Meanwhile, based on the total income of *Kreweng* points (K + Salary), the salary earned by the musicians 8 and singer made their rank go up and shifts the audience 1. The shift in the number of *Krewengs* earned also applies to the musicians 3 and audience 2. Fig. 9 shows data of *Krewengs* point earning (K), while Fig 10 shows data of total *Krewengs* point earning (K + salary).

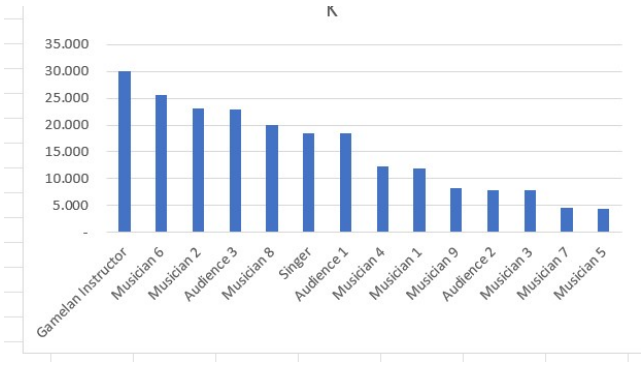

Fig. 9. DATA OF *KREWENGS* POINTS EARNING

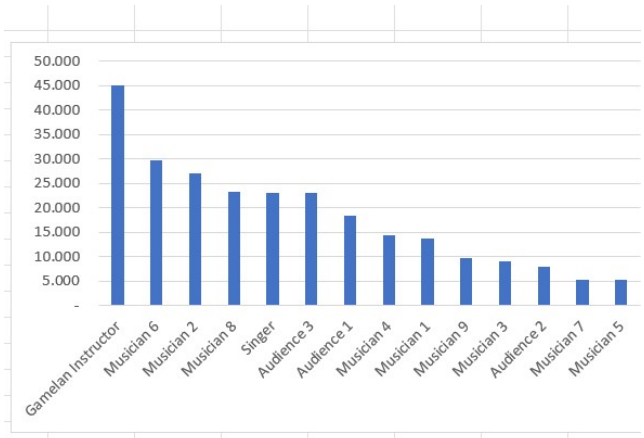

Fig. 10. DATA OF TOTAL *KREWENGS* POINTS EARNING (K + SALARY)

After carrying out the simulation for 10 days, respondents were asked to measure the performance of the GL game based on its ease of playing, its suitability in representing real gamelan world activities, and the level of immersive that can provide a sensation of experience for users being in the virtual gamelan world.

Respondents were asked to rate three statements of "The GL Game is easy to play", "The GL game reflects activities in the real Gamelan world", and "The GL game provides experiences of being in an immersive virtual gamelan world". 14 respondents were asked to determine a value from a range 1-5 which represents strongly disagree to strongly agree. Table IV shows the evaluation results.

TABLE IV. THE GL GAME PERFORMANCE EVALUATION RESULTS

Questions	1	2	3	4	5
The GL game is easy to play	0	0	0	3	11
The GL game reflects activities in the real gamelan world	0	0	2	8	4
The GL game provides experiences of being in an immersive virtual gamelan world	0	0	0	2	12

IV. RESULTS AND DISCUSSION

Based on evaluations on the MVRG, the proportions of the 3D model of instruments and the instrument set layout were considered to be suitable with the real world. Moreover, in general, there was no audio latency problem in communicating between users, even the singer can listen well to the accompanying ensemble music, and the instructor can give verbal instructions well in teaching or correcting the musicians. All of the 9 virtual musicians stated that they had no difficulties, or there was no delay, when communicating in the MVRG. Meanwhile, results of the evaluation of audio and visual latency measurements in playing music in orchestra mode were at the common level, while communicating with other users were at the good level. All the users use the same device, which is HMD Oculus Quest 2-256 GB. This can be assumed that latency may be caused by Internet networks connections obtained by users who were in different locations, or 3D assets that still need to reduce the number of polys.

Synchronization in playing instruments involving real hand movements, virtual hand movements and instrument sounds becomes a problem in the early sessions of musicians playing virtual Gamelan instruments using HMD. After the first five attempts of one hour duration each, four musicians stated that it was difficult, while five users stated that it was very difficult to feel the synchronization between real hand movements, virtual hand movements and instrument sounds. However, in the next five attempts with the same duration, there was an increase in user performance, where three musicians stated that it was not difficult, four musicians stated that it was quite difficult, and two musicians stated that it was difficult. These results show good expectations in achieving synchronization between real hand movements, virtual hand movements and instrument sounds, where the more routines and frequencies solving the user's problems in feeling the synchronization is a condition for a hypothesis.

The cyber sickness factor in the use of HMD is still a problem. All the 14 users felt tired and dizzy after an hour of playing the MVRG. On the other hand, interior and exterior background themes affect the level of cyber sickness. At the initial stage of the evaluation, there were two 3D environmental designs tested, which were the interior environment that placing the Gamelan set in a closed room, and the exterior environment which using an open Gamelan studio with an outdoor view. The evaluation in playing the MVRG using these two background themes takes one hour each. As the results, eight users selected a quite high level of cyber sickness on the exterior background, and two users selected that level on the exterior background. Similarly, six users chose a high level of cyber sickness on the exterior background, and five users selected that level on the exterior background. However, seven users chose cyber sickness with

a very high level on the interior background, and none of the users chose that level on the exterior background. So, the level of cyber sickness experienced by users with an exterior background was less than using the interior background.

Based on evaluations on the GL game, random behavior in playing the GL game by the roles of musician, instructor and audience is indicated by the duration of their existence. This conclusion still needs to be sharpened by simulations with a larger number of users and longer playing time. However, the results obtained are directly proportional to the activities of the Gamelan community in the real world. The opinion of experts involved in this research stated that discipline in following a training schedule is something that is difficult to achieve. This fact was also confirmed by a total of 14 respondents who had never visited GL at the same time. Of the 10 hours (36,000 seconds) scheduled practice duration, the highest total number of respondents in GL at the same time was 10 respondents with a duration of 1,652 seconds, and the lowest was seven respondents with a duration of 1,076 seconds.

The game rules are designed to give users an advantage based on how long they stay in the GL game, and these rules have worked well. The prices of Gamelan buildings and instruments were simulated with values of 100,000, 200,000 and 300,000 *Krewengs* points. Therefore, based on the performance of the Gamelan instructor, with one second equivalent to one *kreweng* point, it will take about 30 days to be able to purchase the minimum Gamelan building and equipment. On the other hand, the ability to buy a Gamelan studio must be balanced with the ability to pay salaries. The costs to pay the salaries of instructors, musicians and singers for the same duration as the simulation require 205,529 points. Therefore, the role of owners and managers is needed as investors who can drive the activities of gamelan studios.

The social presence approach in developing the GL game can be accepted well by all users. All users stated that the GL game is easy to be played. Moreover, two users stated that they quite agree with the statement that the GL game reflects activities in the real Gamelan world, and 12 others stated that they agree and very agree. Immersive evaluation to measure the level of sensation of being in the virtual Gamelan world felt by the user showed good results. The evaluation was based on the activities that can be done in a Gamelan studio in the real world can also be done in the virtual Gamelan studio, and all users claimed agree and very agree that they were able to feel the sensation of being in a real Gamelan studio when they play the GL game.

V. Conclusion and Future Work

The MVRG was designed to be run on the HMD device in order to get a high immersive level. Oculus Quest 2 was selected as the HMD device to play the Gamelan music MVRG. The MVRG supports users from all over the world gathering and experiencing in a virtual Gamelan world. The evaluation carried out showed promising results in the utilization of the metaverse technology as a medium for gathering and playing Gamelan music in the virtual world. Moreover, activities of instructors, musicians, singers, and audiences in the real world can be implemented well in the GL game.

There are still problems in synchronization between real hand movements, virtual hand movements and instrument sounds when playing the instrument, but the frequency in playing the MVRG (using HMD) seems to be one of the important factors that influence these problems. This factor may also have an impact on the user's perceived audio and visual latency. Moreover, the GL game developed using a social presence approach, can implement the activities of the Gamelan community in the real world into the virtual world. The game rules that represent social presence the life of the Gamelan community can be implemented properly. However, more game elements and a wider test involving more respondents from locations spread across various countries is needed to get a more accurate evaluation of the performance of the GL game.

Results in this study can be used as a base line for future development. Further experiments are still needed to maximize the performance of the Gamelan music MVRG, such as the design of 3D environments, both interior and exterior, which can reduce cyber sickness in the use of HMD, the number of vertices and polygons to obtain high quality 3D assets that can be supported by the device.

The GL game next development will be focused on the story development, including implementation of blockchain and cryptocurrencies by offering *Kreweng* tokens. Users can buy *Krewengs* for selling and buying goods and services in the GL game. Transactions can be made between users and GL administrators, or between users. These features are expected to be able to build an economic system in the GL game as a basis for actualizing activities the reflects those in the real Gamelan world.

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Authors` contributions

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Conflict 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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