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Immersive and Challenging Experiences through A Virtual Reality Musical Instruments Game: An Approach to Gamelan Preservation

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Abstract— **This study proposes the preservation of traditional Javanese musical instruments known as Gamelan using an immersive and challenging approach in a virtual reality game format. In an effort to achieve a challenging experience, the gamification is designed by observing musical instrument games selected based on their popularity in the Google Play and the App Store. Oculus Quest 2 which is a stand-alone Head Mounted Displays that provides a high-quality immersive display and more flexibility for users to move is chosen to present the game. Overall, the research target can be achieved based on the evaluation using Mean Opinion Scores. The degree of immersion, presence, likeable, challenging, and the value of cultural preservation contained in the game reaches a range of values between good and excellent. Meanwhile, cybersickness still seems to be a chore for developers to make Head Mounted Displays devices more comfortable.**

Keywords—Virtual reality, Virtual musical instrument, Cultural heritage preservation, Gamelan

I. INTRODUCTION

Computer technology has been used in the development of various application program models. It transforms objects in real life into electronic or virtual forms, and music cannot be separated from this phenomenon. The development of mobile technology makes mobile devices can be used as a medium in transforming musical instruments into electronic and virtual forms, for example, playing virtual musical instruments or learning of musical elements using mobile devices. In recent years the development of virtual reality (VR) technology has opened up great opportunities for the development of virtual reality musical instruments (VRMIs) that can transform musical instruments into 3D models. VRMIs support users to play or learn musical instruments in immersive 3D environments. Moreover, like electronic or virtual musical instruments in other formats, VRMIs reduce costs in comparison to the real instruments [1].

Research in VRMIs has been popular as the costs become increasingly affordable and its immersive presentation capabilities. Although VRMI has not covered much cultural heritage content, some related research has led to it, such as preserving Japanese *tsuridaiko* drum [2] and traditional Chinese musical instruments [3].

This study proposed a preservation of traditional Javanese musical instruments known as Gamelan using VRMIs technology. The preservation is designed based on VR gamification to provide immersive and challenging experiences. The gamification for challenging experiences is designed by observing musical instrument games selected based on their popularity in the Google Play and the App Store. The observation is conducted based on the assumption that a popular and widely downloaded game can represent a challenging experiences presentation. Through this study, Gamelan, which has been designated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a world cultural heritage, can be brought closer to users around the world by providing immersive sensation in playing virtual Gamelan instruments.

II. RELATED WORKS

The technology of VR attempts to bring users into a 3D environment so that they can feel the sensation of presence in a virtual world and act like in the real world. Compared to desktop or cave applications, Head Mounted Displays (HMD) are tools that can provide a sensation for users to feel their presence in the virtual world so that the sensation of immersion can also be felt. However, the correlation between presence and cybersickness are challenges in developing VR applications. The cybersickness can be reduced by reducing sensory mismatch, avoiding stereoscopy and higher view, and increasing intuitiveness of interaction and control of navigation [4]. Immersion is the power of VR applications [5], and immersive VR applications can simply be defined in terms of the quality of the graphics produced by the computer, and the perception of the user which tends to be subjective. The quality of the graphics is about building a 3D environment with the right orientation and proportion of virtual objects [1]. Immersive VR applications can be categorized based on the technology, where VR applications based on mobile VR and HMD are immersive VR applications, while desktop VR and Cave Automated Virtual Environment (CAVE) are non-immersive VR applications [6]. In addition to graphic quality which is also relatively influenced by the ability of 3D artists and the user tastes, immersive VR applications are more easily associated with a strong sense of presence in the virtual world that is obtained by the user, and the use of HMD that provides a stronger sense of presence.

VRMIs can create more engaging experiences with more varied features [7-8]. Interactivity between user actions and feedback, whether in visual, auditory or haptic format, which can be easily interpreted should be considered in developing

VRMIs, and the transformation of musical instruments into virtual formats does not need to be done as closely as possible but content enrichment of virtual features should take precedence [8]. In this context, transformation to virtual format does not mean completely duplicating musical instruments into virtual format, and modification by utilizing features that can be explored from virtual formats and cannot be obtained in the real world makes the performance of VRMIs more useful. Moreover, 3D environments offer the exploration and creativity of the open potential of music, such as the use of the 3D environment as an instrument or score [9]. Stand-alone HMD is used by [10] to develop a VR-based piano learning system with the consideration of being portable and accessible at any time. However, video signal processing to visualize the scene into HMD has a high cost on the Central Processing Unit (CPU), and tolerance for lags in data transfer (latency) should be considered for system hardware processing [11]. On the other hand, the development of HMD technology such as Oculus Quest 2 has been able to deliver various games that display high-quality graphics without latency, and one solution to this problem is to model 3D assets with low-poly techniques.

3D scanner is used to create 3D assets for traditional Japanese musical instruments [2], while data-driven CAD modeling technique of instrument shape and size is used to create 3D musical instruments assets for 3D printing purposes [12]. An attempt to model one of the Gamelan instruments called *saron* into a 3D asset is carried out using traditional 3D modeling technique [13]. However, the number of polygons and vertices is not informed, so it is difficult to determine whether the 3D assets can be categorized into low-poly format.

The preservation of Chinese cultural heritage musical instruments is developed in the concept of a VR museum where users can perform concerts in single-player or multiplayer [3]. Meanwhile, the shape of the Oculus hand controller is modified by adding the shape of the mallet including reshaping the shape of the instrument using the 3D printing technique for playing the *tsuridaiko* drum, a traditional musical instrument from Japan [2]. The idea of combining physical and virtual forms in playing their VRMIs is interesting. It allows users to play virtual instruments with a stronger sense of presence because they are supported by physical tools in playing the instrument.

Virtual Gamelan has been developed in several studies but has not utilized VR technology, for example, [14] developed Smart Gamelan for smart phone platform, [15] developed a Gamelan simulation game based on augmented reality, [16] implemented VR on Gamelan in order to utilize interactive features to simulate the placement of Gamelan instruments to analyze frequency distribution in order to facilitate the identification of instrument sounds.

III. Methodology

In this work, a VRMIs game is developed to bring immersive sensation of playing Gamelan in a virtual world. The content of the game is limited to pitched metallophone percussion instruments which are part of skeleton melodic instruments group. The selected instruments are *demung*, *saron*, *peking* and *slenthem*. The game is named with the Warriors of The Gamelan Skeleton (WGS). During the research, experts from the fields of *Gamelan*, graphic design, animation and games are involved to curate and provide suggestions for the WGS game content. The VR cultural heritage application is divided into two categories, which are documentation and restoration [17]. In general, the purpose in conducting this research is to preserve *Gamelan* by utilizing VR technology in order to develop a VR application that can store Gamelan knowledge and present it in immersive and challenging experiences. Therefore, the development of the WGS game falls into documentation rather than restoration application category.

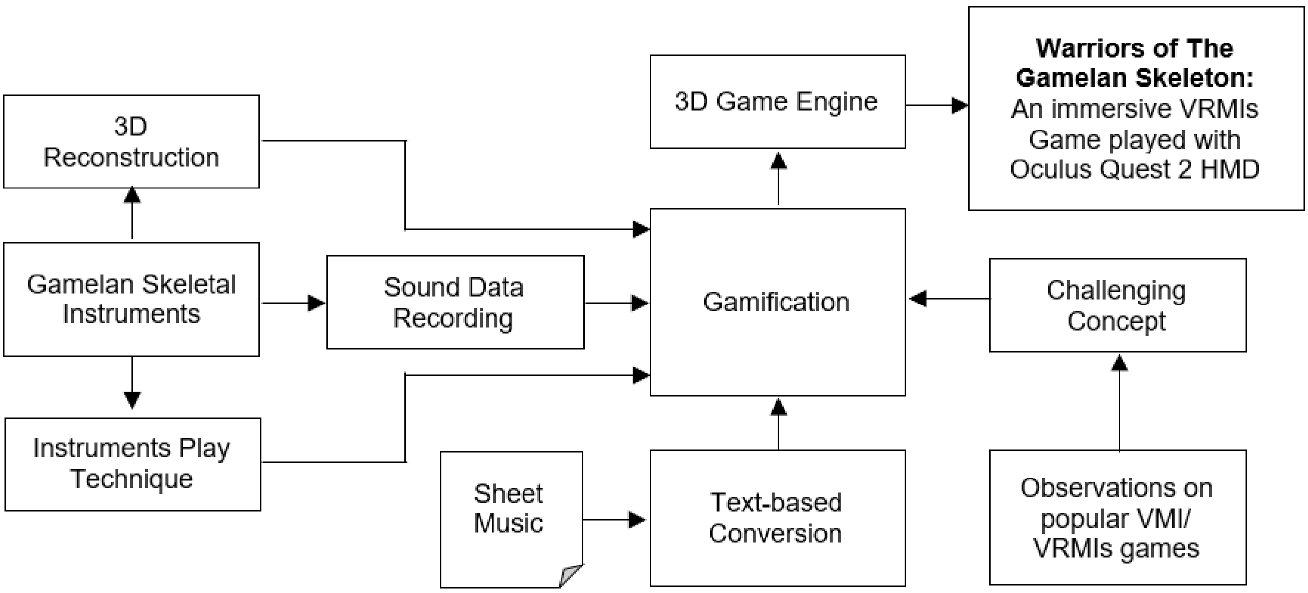

FIGURE 1. THE WGS GAME DEVELOPMENT MODEL

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The WGS game documents the shape, sound and technique of playing the Gamelan skeletal instruments. including the compositions. Documented materials are gamified using a 3D game engine to be presented in an HMD-based VR game for stronger immersive sensation. VR technology can be used to simulate and imitate the real world or the imagination in immersive visualization through a desktop screen or HMD, and HMD is a device that provides a high-quality immersive display [6, 18]. Compared to Oculus Rift, Oculus Quest which is a stand-alone HMD provides more flexibility for users to move. Therefore, Oculus Quest 2 is chosen to present the WGS game. Fig. 1 shows the development model of the WGS game.

A. Introduction to Gamelan

Gamelan is ensemble music consisting of two musical scale systems which are *slendro* and *pelog*. The *slendro* musical scale consists of five notes of 1, 2, 3, 5 and 6. Meanwhile the *pelog* musical scale consists of seven notes of 1, 2, 3, 4, 5, 6 and 7. These two musical scale systems have different audio frequencies. Gamelan uses a musical mode system called *pathet* that are arranged based on dominant notes and their position in the note sequence. The *slendro* musical scale consists of *manyura*, *nem* and *sanga* musical mode systems. Meanwhile the *pelog* musical scale consists of *barang*, *lima* and *nem* musical mode systems. Despite having the same name, the *nem* musical mode system in *slendro* and *pelog* have different dominant and positional characteristics.

Gamelan instruments are divided into structural, melodic skeleton and melody groups. Instruments that fall into the structural group are instruments that determine the musical mode and form of composition, in which there are various forms of composition, for example, *lancaran*, *ladrang*, *ketawang*, *srepegan* and others. The instruments play certain notes in a certain order in the note sequence. Instruments that fall into the melodic skeleton group are instruments that play notes of the melodic skeleton that constitute the skeleton of composition. Within the limitations of meaning, the term skeleton can be interpreted literally like a skeleton in the human body that functions to help the body to stand and move. In this context, the melodic skeleton serves to keep the melody movement within the compositional rules. Instruments that fall into the melody group are instruments that play a melody. Instruments in the structural group are *kethuk*, *kempyang*, *kenong*, *kempul*, *gong* and *kendhang*, and instruments in the melodic skeleton group are *slenthem*, *demung*, *saron* and *peking*, while instruments in the melody group are *rebab*, *gender barung*, *gender penerus*, *bonang barung*, *bonang penerus* and *gambang*.

Lancaran Sayuk Karya, laras Pélog Pathet nem

• 3 • 5   • 3 • 5   • 3 • 5   • 2 • 3

• 6 • 5   • 6 • 5   • 6 • 5   • 3 • 2

FIGURE 2. EXAMPLE OF A SKELETAL MELODY

Melodic skeleton instruments are selected to be implemented in the proposed VRMIs game based on the characteristics of the instruments that can be adapted to formats of popular VRMIs games. Melodic skeleton instruments play melodic skeleton notes as illustrated in Fig. 2, [21 of a melodic skeleton for a *Lancaran* form composition entitled *Sayuk Karya* played with the *pelog* musical scale and the *Nem* musical mode system.

B. Compositions Data Representation

The WGS game is designed to be able to detect the user's play based on the accuracy of hitting the metal bars of the instrument according to the notes and beat tempo in the composition. Instead of using composition data in audio format, composition data in sheet music format is preferred for use in the game. The data in sheet music is converted into text, and then automatic algorithms for playing the instrument based on the notes sequence are applied to the musical accompaniment. This method makes it easy to add to the collection of compositions in the game.

Sheet music contains symbols that represent the musical elements of the composition such as the dotted note which represents a moment of silence. The data are then converted into a text-based format using Ghending Scientific Pitch Notation (GSPN), a model for writing musical elements of Gamelan compositions proposed by [20]. The GSPN model converts the dotted notes to number of 0 for computational processing. An example of a text-based conversion of sheet music data as shown in Fig. 2 would be: (0, 3, 0, 5, 0, 3, 0, 5, 0, 3, 0, 5, 0, 2, 0, 3, 0, 6, 0, 5, 0, 6, 0, 5, 0, 6, 0, 5, 0, 3, 0, 2). The text-based conversion is applied to all sheet music used as the dataset which consists of 20 compositions of the *pelog* musical scale and 20 compositions of the *slendro* musical scale.

C. 3D Reconstruction

Typology analysis on the shape of the instruments is carried out by observing the shape and ornament, material and texture, including measuring the dimensions of the instrument. Fig. 3 shows the photo documentation of the typology analysis activities using Gamelan set from Universitas Dian Nuswantoro, Indonesia.

FIGURE 3. PHOTO DOCUMENTATION OF THE TYPOLOGY ANALYSIS ACTIVITIES

Based on observations on the shape of the instrument which has a relatively uncomplicated basic construction, and consultation with Gamelan experts who do not mind if the ornament detail on the instrument is reduced, traditional 3D modeling technique is chosen for 3D reconstruction phase. Three instruments of *demung*, *saron* and *peking* share the same shape but differ in size, while the *slenthem* instrument has a different form. Therefore, 3D modeling phase only creates two instrument shapes, one shape is for the *slenthem* instrument and the other shape is modified for *demung*, *saron* and *peking* instruments using duplication technique and then adjusting the size of the two duplicated 3D models.

Instead of using photogrammetry, in order to achieve low-poly models, 3D modeling is fully conducted using 3Ds Max software by applying polygonal modeling technique. Polygonal modeling technique provides more flexibility in controlling the number of polygons. As the results, the seven-notes pelog musical scale instrument of demung can be modeled in 5.016 polygons and 4.952 vertices. So, saron and peking instruments are also formed in the same number of polygons and vertices. Meanwhile slenthem instrument is formed in 14.860 polygons and 10.014 vertices. The number of polygons and vertices is reduced in modeling the five-notes slendro musical scale instrument.

There is no rule that defines the number of polygons or vertices in a 3D model to be categorized as a low-poly model, but some literature states that low-poly models range from 10.000-15.000 polys. Thus, the 3D models of the instruments can be categorized as low-poly models. Fig. 4 shows results of 3D modeling for the seven-notes pelog musical instruments of demung, saron, peking and slenthem.

FIGURE 4. ILLUSTRATION OF LOW-POLY MODELING FOR THE INSTRUMENTS (LEFT), 3D MODELING RESULTS (RIGHT)

D. Sound Recording and Technique of Playing Instruments Acquisition

Sound analysis is carried out by involving Gamelan musicians to play the instrument by hitting the metal bars one by one, and playing several compositions. The activities are recorded to obtain visual and audio data as material for sound analysis, including technique of playing the instruments. After practicing the technique of playing the instrument, the team of researchers, experts and musicians conducted a focus group discussion to acquire theoretical knowledge of the technique of playing instruments. Fig. 5 shows a photo documentation of musicians' playing observations and recording instrument sound data, where the data for each note is recorded separately.

FIGURE 5. PHOTO DOCUMENTATION OF INSTRUMENT PLAYING TECHNIQUE OBSERVATION AND RECORDING OF TONE SOUND DATA

The results of recording sound data for each note are saved in .wav format with the names pd, ps, pp and pl to label the sound files of the seven-notes *pelog* instruments of *demung*, *saron*, *peking* and *slenthem* respectively. Further, each label is given an index in order to label the sound of each note, for example, pd1.wav, pd2.wav, pd3.wav, ..., pd7.wav for the sound of each note of the seven-notes *pelog* instrument of *demung*. The same labeling technique is also applied to the five-notes *slendro* instruments with sd, ss, sp and sl. The five-notes *slendro* instruments are given an index of 1 to 5, i.e. the sound of *peking* instrument is labeled with sp1.wav, sp2.wav, sp3.wav, sp4.wav and sp5.wav, for notes 1, 2, 3, 5 and 6, respectively. Later, when programming the play automation of the note sequence, data of each note 5 and 6 will be subtracted by 1 to adjust the index of the label of the sound data.

E. Instruments Play Technique

A focus group discussion conducted to formulate instrument playing techniques resulted in an agreement to implement the note-playing automation algorithm proposed by [14], where the time tolerance to play the current note faster than the formal time is -328 milliseconds of the current millisecond, and the time tolerance to play the current note slower than the formal time is +246 milliseconds of the current millisecond. The algorithm works by calculating the time tolerance in playing the note, which is the time that is not too fast or not too slow in based on its formal time. Formal time is the time interval in each beat, for example, the time interval is 1000 milliseconds for slow tempo play. The following is the algorithm to randomly determine the time to play.

T = tempo in milliseconds
C = number of beats in the composition.
B = index of beats
M = note sequence data
Z = sequence of playing times based on multiples of tempo = ((T × 1), (T × 2),..., (T x C))
X = tolerance time to play that less than current Z
Y = tolerance time to play that more than current Z
W = time to play

Algorithm: Notes play automation

```
millisecond = 0
B = 0
While B < C Do
    start counting milliseconds
    W = random (Z [B] - X, Z [B] + Y)
    If millisecond ≥ W Then
        If M [B] > 3 And slendro Then
            M [B] -= 1
        End
        play M [B] // all instruments
        B += 1
        W = random (Z [B] - X, Z [B] + Y)
    Else If millisecond ≥ W/2 Then
        play M [B] // peking instrument
    End
    If B > C Then
        B = 0
        millisecond = 0
    End
End
```

The notes play algorithm works by play note-by-note in the note sequence based on the interval time of tempo. For example, let the note sequence M be (0, 3, 0, 5, 0, 3, 0, 5, 0, 3, 0, 5, 0, 2, 0, 3, 0, 6, 0, 5, 0, 6, 0, 5, 0, 6, 0, 5, 0, 3, 0, 2), and the tempo T set to 1000 milliseconds. The number of beats in the composition C is the element length of M, which is 32. Thus, the sequence of playing time Z in milliseconds is (1000, 2000, …, 32.000). With X represents the tolerance time to play that less than the current Z set to -328, and Y represents the tolerance time to play that more than the current Z set to 246, the time to play W will be a random value obtained from the range current Z – X and current Z + Y, where the current Z is indicated by the index of beats B. *Demung, saron* and *slenthem* instruments are played once in one beat, so they are played when millisecond is greater than or equal to the time to play W. Meanwhile *peking* instrument is played twice in one beat, so it is played in the same time calculation with *demung*, *saron* and *slenthem* instruments, and when millisecond is greater than or equal to half of the time to play W.

F. Gamification and Game Programming

Virtual musical instruments (VMIs) and VRMIs games that are popular on Google Play and the App Store become objects of observation to be used as a basis in designing the WGS game. The observation results showed that the visualization of notes into various variations of animated objects becomes a trend in VMIs games, including VRMIs games. Animation for objects that visualize notes is presented by specifying a trajectory for the object's movement at a speed that matches the tempo of the composition being played. For example, on the virtual piano instrument there are games Magic Piano by Smule, Piano-Play and Learn songs by Yokee, while on the guitar hero game genre there are games Guitar Flash by Games X Informatica Eireli, Rock Hero-Guitar Music Game by Guitar and Music Games, and Guitar music hero: Rhythm Game by Music Hero Games. On the other hand, observations made on VMIs or VRMIs games with Gamelan as the object have not found challenges that are as interesting as the games previously mentioned. The Smart Gamelan application: Demung Laras Pelog by Gamelan Research Project which is a Gamelan VMI learning in game format has visualized the notes into animated objects with a different approach, which is highlighting the squares that become the background of the tone based on the beats that run in the composition.

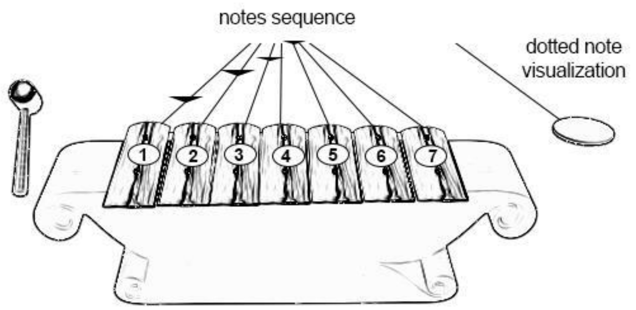

FIGURE 6. SKETCH (ROUGH DESIGN) OF THE INSTRUMENTS AND IT'S GAME PLAY

Consultations conducted with animation and graphic design experts concluded that compared to notes visualization and animation as in Smart Gamelan games, notes visualization and animation using movement trajectories with object movement speed control as in guitar hero games provide a more challenging sensation because it includes collision detection event. On the other hand, the design of VMI or VRMI for the preservation of cultural heritage must be carried out carefully and thoroughly so the presentation does not cause misunderstandings about cultural heritage objects. In this context, consultation with Gamelan experts is carried out by explaining the research objectives, game designs and showing illustrations using examples of guitar hero games, and the game play sketch as shown in Fig. 6, where the dotted note that represents a moment of silence is visualized using a cylindrical object.

The cylindrical object and the animation trajectory of the dotted notes are intentionally positioned apart from the instrument to clearly distinguish the notes in the dotted scale system. In reality, a dotted note represents the moment of silence, in which the instruments do not play a note. In the context of learning, the system must be able to detect the user's skills in determining each beat. Therefore, the user must hit the cylinder symbol so that the system can detect that the user has known the time in each beat and can score proportionally.

Gamelan experts support the idea and design proposed in this research by underlining that although there is an addition shape to visualize the dotted note, the shape of the instrument, including the mallet, modeled in 3D must match the real instrument, and the tempo measurement in playing the instrument must be accurate.

In order to play the WGS game, users must select the type of the musical scale first, then selects the composition displayed in the list. Taking into account the skill variations of the user, the tempo of the game is set into four levels, which are very slow, slow, medium and fast with the time interval values of 1200, 1000, 800 and 600 milliseconds respectively. The game starts after the user determines the type of scale, composition and tempo. When the WGS game is played, the notes playing automation algorithm will be run as accompaniment music, and the accompaniment music automation will repeat from the beginning after the current note reaches the last note. The game measures the user's skill in playing the instrument based on the accuracy of hitting the metal bars and the timing of hitting them. Accuracy in hitting metal bars is determined based on the notes played and time tolerances determined by the notes playing automation algorithm.

The shape of the controller is similar to the instruments mallet, making it easy to transform the technique of hitting metal bars virtually. The user simply swings the right controller to hit the metal bars in playing the virtual instrument as in the real performance. Fast feedback from user action is designed by immediately changing the color of the metal bar being hit to red if it doesn't match the tone and tempo, and turning it green if the metal bar being hit matches the tone and tempo. Color changes based on the user's accuracy in playing the instrument occur in less than one second, after which the metal bar texture returns to its original state.

The game play is not limited to a single block of composition. Users can play the composition repeatedly and stop at any note. Therefore, scoring is done by counting the number of correct notes played divided the total number of notes played, and this includes dotted notes. For example, after the user plays a composition with a length of 32 notes repeatedly and stops at the repetition at the 45^{th} note, the total notation played is 45. Moreover, if the user plays 37 notes correctly, the accuracy score of the game obtained is 37 / 45 = 82%.

The WGS game development is conducted using Unity 2020.3.2 2f1 software which supports XR SDK plug-in framework. Extended Reality (XR) is described in [20] as follows:

> "An umbrella term encapsulating Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and everything in between. Although AR and VR offer a wide range of revolutionary experiences, the same underlying technologies are powering XR"

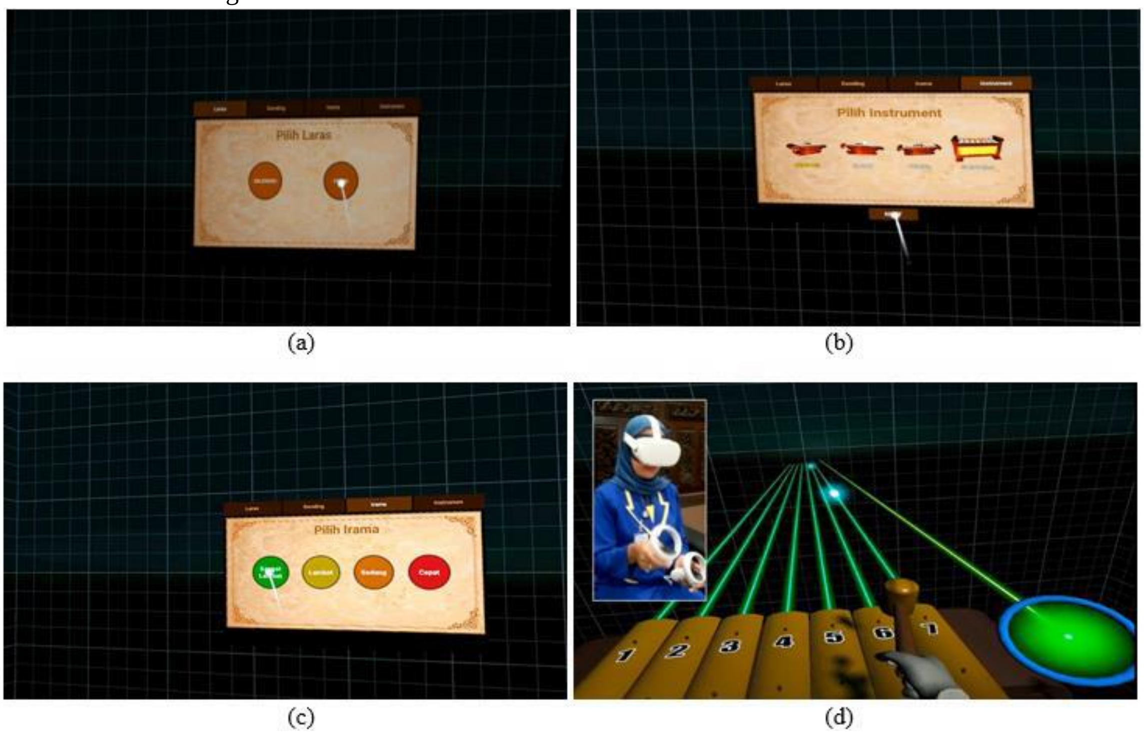

FIGURE 7. SCREENSHOTS OF SELECTING MUSICAL SCALE SYSTEMS (a), SELECTING MUSICAL INSTRUMENTS (b), SELECTING TEMPO (c), AND DURING THE PLAY (d)

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The WGS game navigation is designed to be as simple as possible by limiting games to contain no more than two pages. The first page is a splash screen that displays the game logo, and the second page is a menu page that contains a choice of types of musical scales, compositions and tempos, as well as the Play button to start the game.

All assets created in the 3Ds Max program are imported into Unity, and the programming phase begins. Overall, the development duration of the WGS game took one and a half months from the initialization stage to programming, which is distributed in data collection, instrument play formalization, 3D reconstruction and programming, approximately one week each. Fig. 7 shows screenshots of the WGS game with an inset containing a photo of the user while playing the game.

IV. RESULTS AND DISCUSSION

This study aims to preserve traditional musical instruments with a popular approach by implementing immersive and challenging experiences through a VRMIs game of WGS. The game play contains accompaniment music that plays a composition chosen by the user, in which the user must play the composition by hitting metal bars according to the notes sequence and tempo. The evaluation is carried out in two stages, which are the stage of measuring accuracy in the automation of compositional play based on the notes sequence and tempo, and the stage of measuring the appropriateness of the immersive and challenging experiences in order to preserve Gamelan.

Measurement of accuracy for play automation based on note and tempo is carried out by involving three Gamelan experts to listen and assess the system in playing the composition. Each expert gave an assessment based on the five compositions listened to, and each expert rated a different composition. Fifteen compositions used for this evaluation are randomly selected and distributed from 40 compositions embedded in the system with eight compositions representing the pelog musical scale and seven compositions representing the slendro musical scale. Considering the importance of accuracy in the play automation, the assessment given by the expert on each composition played consists of two choices, which are accurate or inaccurate. The results of expert assessments show that the system is able to play compositions based on tone and tempo accurately. Accuracy in the automation of the fifteen compositions played by the system reached 100% where all experts stated that the five compositions that each expert listened to had been played by the system accurately.

Next evaluation was to measure the appropriateness of the immersive and challenging experiences in order to preserve Gamelan. This type of evaluation is usually carried out using measurements based on user acceptance. An application containing VR tours of cultural heritage sites developed by Park et al. [21] uses user acceptance test to measure elements of presence, enjoyment, post VR attitude change, and visit intention. In short, the elements used represent the level of immersion in encouraging users to act further with the desire and action to physically visit cultural heritage sites. Meanwhile, Zamora-Musa et al. [22] who developed a similar VR application conducted user acceptance test by adopting the Software Usability Measurement Inventory (SUMI) method, a method used to measure software quality is based on an assessment of the scale of efficiency, affect (likeability), helpfulness, control, learnability and global measurement, made by users [23]. However, based on the characteristics of the WGS game, user acceptance test performed in this study used four elements to measure the degree of immersion, challenge, cultural heritage preservation, and cybersickness, in which each element consists of two interrelated questions as follows:

Immersion (R1):

R1.1 : The WGS game provides an enjoyable experience that exceeds the experience obtained from playing games using other platforms.

R1.2 : I can feel the sensation of playing Gamelan for real.

Challenging (R2):

R2.1 : I am excited to improve my playing performance so that I can achieve higher scores.

R2.2 : I am very interested to play the WGS game again.

Cultural heritage preservation (R3):

R3.1 : The experience I got from the WGS game made me understand more about how to play Gamelan instruments

R3.2 : The cultural heritage preservation values presented in the WGS game make it a recommended game

Cybersickness (R4):

R4.1 : I do not feel cybersickness when playing the WGS game.

R4.2 : I can play the WGS game longer than 15 minutes at a time.

The results of the questionnaire are analyzed using Mean Opinion Scores (MOS). MOS uses subjective assessments from users to measure quality of various stimulants or systems, for example quality of audio as in [24], 3D visualization as in [25], and image as in [26-27]. The calculation of the quality scale matrix in MOS using the formula: (ΣRn) / NNn=1, where R is the individual score of the stimulus given by N subjects. Twenty respondents are selected randomly by screening based on minimum age of 17 years and over, and although the evaluation did not aim to obtain a subjective assessment based on gender, gender distribution is determined proportionally with 10 males and 10 females. The last criterion was that the respondents must have experience playing game on either a desktop, mobile, AR, MR or mixed reality platform.

After experiencing the WGS game, respondents are asked to answer the questions using a value range of 1-5 which represents the user opinion scale from strongly disagree to strongly agree where strongly disagree is equal to very bad and strongly agree is equal to very excellent. The test results using MOS are shown in Fig. 8 and Table 1. The MOS results show that the WGS game has immersion degrees between good and excellent with R1.1 which represents likeable reaches a value of 4.1, and R1.2 which represents presence reaches a value of 4.5. The MOS results showing the relationship between R1.1 and R1.2 can be used to draw the conclusion that the WGS game is immersive, and likeable because it gives a sense of presence. The same achievement also applies to the challenging element (R2) and the cultural heritage element (R3) with degrees between good and excellent. The questions of R2.1 which represents excitement in increasing score, and R2.2 which represents desire to play more achieve values of 4.4 and 4.2, respectively. Meanwhile questions R3.1 and R3.2 which contain the value of cultural heritage preservation showed interesting results, where the introduction of *Gamelan* to respondents in game format gave positive results and even respondents are motivated to share it. On the other hand, cybersickness (R4) is still a problem in VR. The MOS results show that most of the respondents do not agree with the statement R4.1 and R4.2 with achievement values of 2.1 and 1.2, respectively. The possibility is that HMD technology still has weaknesses in terms of convenience in use, or it could be caused by users who are not familiar with this technology. However, the design of the WGS game can be ruled out of the cause of cyber disease. The MOS results from R4 are inversely proportional to R1, R2, R3 where the three elements support the evidence that the user's desire to play the WGS game is at a high degree, which is between agree and strongly agree.

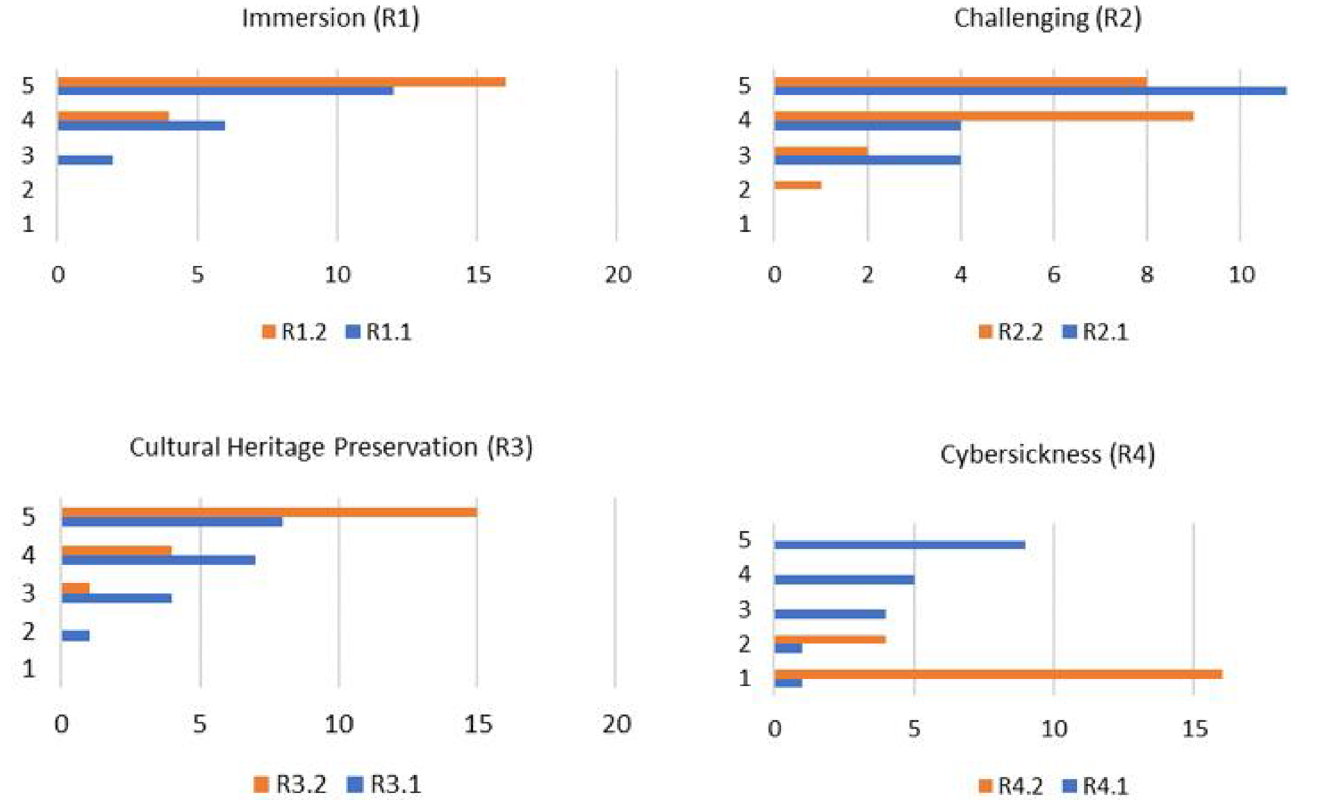

FIGURE 8. MOS EVALUATION RESULTS IN GRAPHS

TABLE I. MOS EVALUATION RESULTS

R1		R2		R3		R4	
1	*2*	*1*	*2*	*1*	*2*	*1*	*2*
4.5	4.8	4.4	4.2	4.1	4.7	2.1	1.2

V. CONCLUSION AND FUTURE WORK

Immersive and challenging experiences through a VRMIs game is proposed to support Gamelan preservation. Overall, the research target can be achieved through the development of the WGS game. The degree of immersion, presence, likeable, challenging, and the value of cultural preservation contained in the WGS game reaches a range of values between good and excellent. Meanwhile, cybersickness still seems to be a chore for developers to make Head Mounted Displays devices more comfortable.

The demo of the WGS game can be seen on YouTube: www.youtube.com/channel/UCyvCuCEOmCREardSaxPO0UQ. Future work will focus on developing the WGS game into a multiplayer game format that allows interaction between users to play Gamelan in different locations. Thus, the concept of Gamelan music in an orchestra can be brought into the virtual world as in Metaverse applications.

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REFERENCES

[1] R. Zender, A.H. Knoth, M.H. Fischer, and Ul. Lucke, "Potentials of virtual reality as an instrument for research and education", i-com, 18(1), pp. 3-15, 2019. Doi: 10.1515/icom-2018-0042.

[2] J. Granzow, and A. Camci, "Recreating a rare instrument using VR and fabrication: A hyperreal instrument case study". Forum Acusticum, Lyon, France, pp. 655-658, 2020. Doi:10.48465/fa.2020.0847. hal-03234058.

[3] Q. Jia, "Application of Chinese traditional musical instruments", Scientific and Social Research, 3(1), pp. 80-84, 2021. Doi: 10.36922/ssr.v3i1.1063.

[4] S. Weech, S. Kenny, and M. Barnett-Cowan, "Presence and cybersickness in virtual reality are negatively related: A review", Front. Psychol. 10(158), 2019. Doi: 10.3389/fpsyg.2019.00158.

[5] Z. Lv, "Virtual reality in the context of Internet of Things", Neural Comput & Applic, 32, pp. 9593–9602, 2020. Doi: 10.1007/s00521-019-04472-7.

[6] J. Radianti, T.A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda", Computers & Education, 147, 103778, 2020. Doi: 10.1016/j.compedu.2019.103778.

[7] J. Brett, T. Gladwell, T, N. Xu, P. Amelidis, T. Davis, and C. Gatzidis, "Developing games for the purposes of rote learning for keyboard and piano", IEEE Conference on Games (CoG), pp. 724-727, 2020. Doi: 10.1109/CoG47356.2020.9231779.

[8] S. Serafin, C. Erkut, J. Kojs, N.C. Nilsson, and R. Nordahl, "Virtual reality musical instruments: State of the art, design principles, and future directions", Computer Music Journal, vol. 40(3), pp. 22–40, 2016. Doi:10.1162/COMJ a 00372.

[9] A. Çamcı, and R. Hamilton, "Virtual 3D environments as composition and performance spaces", Journal of New Music Research, 49(1), pp. 104-113, 2020. Doi: 10.1080/09298215.2019.1703013.

[10] K. Okasaki, and M. Makino, "A VR-based piano self-training portable system on standalone HMD", Proc. SPIE 11766, International Workshop on Advanced Imaging Technology (IWAIT) 2021, 117662I, 2021. Doi: 10.1117/12.2591031.

[11] K. Brunnström, E. Dima, T. Qureshi, M. Johanson, M. Andersson, and M. Sjöström, "Latency impact on quality of experience in a virtual reality simulator for remote control of machines", Signal Processing: Image Communication, 89 (2020) 116005, 2020. Doi: 10.1016/j.image.2020.116005.

[12] S. Cottrell, and J. Howell, "Reproducing musical instrument components from manufacturers technical drawings using 3D printing: Boosey & Hawkes as a case study", Journal of New Music Research, 48(5), pp. 449-457, 2019. Doi: 10.1080/09298215.2019.1642362.

[13] Y.P. Yuda, and M.N.L. Azis, "3D modeling the gamelan of saron as a documentation of cultural heritage preservation efforts", Journal of Physics: Conference Series, 1375, 2019. Doi: 10.1088/1742-6596/1375/1/012036.

[14] A.Z. Fanani, K. Hastuti, A.M. Syarif, and A.R. Mulyana, "Rule-based interactive learning application model on how to play music instruments", International Journal of Emerging Technologies in Learning, 15(15), pp. 52-63, 2020. Doi: 10.3991/ijet.v15i15.11486.

[15] F. Permana, H. Tolle, F. Utaminingrum, and R. Dermawi, "Development of augmented reality (AR) based Gamelan simulation with leap motion control", International Journal of Interactive Mobile Technologies, 13(12), pp. 120–135, 2019. Doi: 10.3991/ijim.v13i12.9270

[16] C.F. Setiyawan, and M. Shobri, "Blocking Gamelan instruments frequency in virtual reality", Proc. SPIE 11515, International Workshop on Advanced Imaging Technology, 1151526, 2020. Doi: 10.1117/12.2566939.

[17] A. Z. Fanani, K. Hastuti, A.M. Syarif, P.W. Harsanto, "Challenges in developing virtual reality, augmented reality and mixed-reality applications: Case Studies on a 3D-based tangible cultural heritage conservation", International Journal of Advanced Computer Science and Applications, vol. 12, issue 11, pp. 219-227, 2021. Doi:10.14569/IJACSA.2021.0121126.

[18] G. Makransky, and G.B. Petersen, G.B, ""The cognitive affective model of immersive learning (camil): A theoretical research-based model of learning in immersive virtual reality", Educational Psychology Review, vol. 33, pp. 937–958, 2021. Doi: 10.1007/s10648-020-09586-2.

[19] A.M. Syarif, A. Azhari, S. Suprapto, and K. Hastuti, "Human and computation-based music representation for Gamelan music", Malaysian Journal of Music, vol. 9, pp. 82-100, 2020. Doi: 10.37134/mjm.vol9.7.2020.

[20] https://www.qualcomm.com/research/extended-reality (accessed on January 5, 2022).

[21] H. Park, J. Kim, S. Bang, and W. Woo, "The effect of applying film-induced tourism to virtual reality tours of cultural heritage sites", 3rd Digital Heritage International Congress held jointly with 24th International Conference on Virtual Systems & Multimedia, San Francisco, CA, USA, pp. 1-4, 2018, Doi: 10.1109/DigitalHeritage.2018.8810089.

[22] R. Zamora-Musa, J. Vélez, and H. Paez-Logreira, "Evaluating learnability in a 3D heritage tour", Presence: Virtual and Augmented Reality, 26(4), pp. 366-377, 2017. Doi: 10.1162/PRES_a_00305.

[23] https://sumi.uxp.ie/about/whatis.html (accessed on January 9, 2022).

[24] D. Pal, C. Arpnikanondt, S. Funilkul, and V. Varadarajan, "User experience with smart voice assistants: The accent perspective", 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT), pp. 1-6, 2019. Doi: 10.1109/ICCCNT45670.2019.8944754.

[25] G. Meynet, J. Digne, and G. Lavoué, "PC-MSDM: A quality metric for 3D point clouds", 11th International Conference on Quality of Multimedia Experience (QoMEX), pp. 1-3, 2019. Doi: 10.1109/QoMEX.2019.8743313.

[26] P.C. Madhusudana, and R. Soundararajan, "Subjective and objective quality assessment of stitched images for virtual reality", IEEE Transactions on Image Processing, 28(11), pp. 5620-5635, 2019. Doi: 10.1109/TIP.2019.2921858.

[27] S. Katsigiannis, J. Scovell, N. Ramzan, L. Janowski, P. Corriveau, M.A. Saad, and G. Van Wallendael, "Interpreting MOS scores, when can users see a difference? understanding user experience differences for photo quality", Quality and User Experience, 3(6), 2018, Doi: 10.1007/s41233-018-0019-8.