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Virtual exhibition systems using virtual reality technology

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ABSTRACT

Exhibitions are an activity that can bring a lot of benefits to a company. By participating in an exhibition, a company can carry out promotions to increase their sales and improve their company image. However, there are several shortcomings that can be found with conventional exhibitions held in a face-to-face manner. These exhibitions cost a lot of money, run for only a relatively short period of time, and are limited by the location of the exhibition. Because of this, the idea came up to create a virtual exhibition system which could be used as an alternative to conventional exhibitions. The development of a virtual exhibition system for this research was carried out using the Unity game engine. At the virtual exhibition, users can choose which exhibition they want to visit and enter the exhibition room view products and find information about them. Evaluation is carried out using a user acceptance test with Likert scale questions. The evaluation results show a user satisfaction level of 92.7% among the 18 users who have tested the application. With this, it can be said that the virtual exhibition system based on virtual reality technology has been successfully built.

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1. INTRODUCTION

Exhibitions are an important service industry sector, both in terms of business value, as well as in terms of benefits for other economic sectors as a promotional vehicle [1]. Various large, very prestigious exhibitions have been held as places to promote products, services and technology in many cities around the world. Many companies are interested in participating in exhibitions within their industry group. This is because by participating in the exhibition, the company will be better recognized by both its industry and consumers. Apart from that, sales and company image can be improved through promotional activities carried out at exhibitions [2]. Therefore, it is not difficult to believe that there are many companies who are willing to allocate large budgets to participate in exhibitions.

Exhibitions generally require large costs. Costs can be incurred for various things such as renting space, building stands, paying exhibition staff, food allowance, promotional materials and so on [3]. This makes exhibitions one of the largest components in a company's marketing budget [4]. And, the relatively large costs incurred by the company will only be utilized for a relatively short period of time. In addition, visitors may also experience difficulties in visiting exhibitions as they will be limited by the location and capacity of the exhibition venue.

Seeing the drawbacks of conventional exhibitions, the idea came up to build a virtual exhibition system using virtual reality technology. This system can bring a number of advantages for companies compared to conventional exhibitions. The costs spent will be cheaper [5]. This is because building stands or paying exhibition staff is no longer required. The benefits received for the costs incurred will also be valid

for a longer period of time. They will not be limited to just a few days as with conventional exhibition periods. Products and services can also be updated according to company needs. In addition, a virtual exhibition can be offered throughout the world in countries that are initially difficult to reach using conventional exhibitions [5].

Not only that, virtual exhibitions can also benefit exhibition visitors. It will be easier for them to access the exhibitions they want to visit. Visitors don't have to bother leaving the house, experience traffic jams on the road, or queue to enter the exhibition doors. Apart from that, visitors do not need to be in crowded exhibition rooms. Rather, they can search for information or products of interest more comfortably from their own devices. The exhibition will also be available for visitors to access throughout the day with no closing time.

The use of virtual reality technology will also bring its own benefits. Implementing virtual reality in applications can create a deeper and more interesting user experience [6]. Users are more engaged in the VR experience and can interact with information more naturally [7]. An immersive atmosphere can be created where users feel as if they are at a real exhibition. This unique aspect of having virtual reality will help differentiate the applications being built from other applications that are already available. This uniqueness can also increase user interest in choosing the application.

However, virtual exhibitions also have their drawbacks. Difficulty in measuring effectiveness, low quality of interaction, unsupportive technology, and visitor incivility are some of the challenges faced by virtual exhibitions [5]. However, it is hoped that with a virtual exhibition system, exhibitors will have an alternative to conventional exhibitions. With these additional options, companies can choose marketing strategies that are better suited to their individual needs.

Similar research regarding virtual exhibitions has been carried out previously by a research paper titled "Evaluation of virtual tour in an online museum: exhibition of architecture of the forbidden city" [8]. In it, a virtual tour of an online museum exhibition was constructed where users can move to pre-determined locations using movement buttons. User evaluation done in this research found that although the application was able to create a good sense of reality, the interactivity and methods of navigation in the application were found to be lacking. Another research paper titled “Efficacy of virtual reality in painting art exhibitions appreciation” created a virtual art gallery using virtual reality technology which was then also evaluated by user testing [9]. This research found that the use of virtual reality can be suitable for creating virtual art exhibitions. One more research paper titled “Virtual reality exhibition platform” created virtual environments to represent a virtual exhibition which was done with the implementation of virtual reality [10].

However, the research papers previously mentioned are lacking in some areas. The first research paper did not implement virtual reality technologies in its virtual exhibition. There is also a difference in the type of exhibitions being made. The first research paper created a virtual museum tour while the second created a virtual art gallery. These are different from the type of exhibition that this research paper would like to explore, namely the ones in which companies can market their products and services. The third research paper successfully created this type of exhibition. However, it did not conduct any user testing and evaluation to see the efficacy and levels of user satisfaction of the application.

As such, this research aims to design and build a virtual exhibition system which uses virtual reality technology. This research also aims to measure the level of user satisfaction towards the virtual exhibition application. This paper will first discuss a literature review regarding topics related to the research. The methodology of the research and how it was carried out will then be laid out. The results and findings of this research will be discussed next followed by conclusions that can be taken from this research.

2. LITERATURE REVIEW

2.1. Virtual exhibitions

Virtual exhibitions are often referred to as digital exhibitions, online exhibitions, online galleries, exhibitions in cyberspace. By using virtual exhibitions, exhibitors can develop the material presented in a broader and more lasting manner to attract the interest of exhibition visitors. In addition, the use of virtual exhibitions can save production costs, such as saving on insurance, shipping and installation costs [11]. And, virtual exhibitions can reach more people than conventional exhibitions. This is because everyone can access the information they need, as long as they have a computer or another device. Virtual exhibitions are also not limited by exhibition opening or closing times and can be available 24 hours unlike conventional exhibitions [12].

In the current era, conventional exhibitions that are usually held by museums, libraries and other cultural organizations have now begun to switch to virtual exhibitions. This is because there are many benefits that can be obtained, such as convenience and cost savings. Virtual exhibitions can also be carried out via online video, streaming, social media, or via online chat. Each virtual exhibition method has its own advantages and disadvantages [13].

2.2. Virtual reality

Virtual reality is a technology that implements a virtual 3D environment that users can navigate and interact with [14]. The nature of virtual reality makes it different compared to other forms of digital media. Users are more involved in the virtual reality experience and can interact with information more naturally in the virtual world [7]. This is because virtual reality can provide an experience that feels more real [15]. Several different types of hardware are required to be able to use virtual reality. This includes stereoscopic displays, input devices, motion tracking hardware, and desktop/mobile platforms [16].

Virtual reality is often used by developers in various fields such as education, health and entertainment [17]. The adoption of virtual reality technology occurs because of a number of benefits obtained from its use. For example, the use of virtual reality can have a positive impact on students' ability to absorb learning materials [18]. The main advantage that virtual reality has is the freedom it gives users in the way they interact and navigate their virtual environment. This helps create a more realistic and natural experience for users [19].

2.3. Non-player character

A non-player character is an interactive agent that is not controlled by the user. Instead, they are controlled by the AI system in the application or system where they are implemented. The behavior and actions of a non-player character can be determined rigidly or created dynamically as the application progresses based on the design and algorithms used [20]. There are several functions that can be fulfilled using non-player characters. They can be used to teach users about features or mechanics in a game or application. They can act as allies who can help the user or enemies who will fight the user. They can also be neutral characters in virtual environments that can help contribute to atmosphere and realism [21].

One popular way that is often used to control non-player characters is to use finite state machines [22]. In a finite state machine, non-player characters will have several predetermined actions or behaviors that are represented as a state. The non-player character will then transition from one state to another when an input is received or a condition is met. Another way to implement non-player characters is to use behavior trees. A behavior tree consists of nodes that are connected in one direction to each other. Behavior trees start their execution from the root node which acts as the first node. After that there are several different nodes that can be used to model the desired behavior such as fallback, sequence, parallel, decorator, action, and condition nodes [23].

2.4. Pathfinding

Pathfinding is the process of finding the shortest route between two points while avoiding obstacles or obstructions [24]. Pathfinding is often used in game development, such as to move characters. Pathfinding is also used in other fields such as autonomous vehicle navigation, robotics, and logistics. The goal of a pathfinding algorithm is to find the optimal path by minimizing criteria such as distance or time. However, more resources are needed to maximize the quality of the discovered paths. Because of this, there are many pathfinding algorithms that have been created such as the Djikstra algorithm or A* which have their own balance between performance and quality of results [25].

In the context of a game, pathfinding is used to control characters, both player and non-player, and other elements [26]. With pathfinding, a good route can be calculated so that the character can traverse the virtual environment realistically. The algorithm that is often used in game development is the A* algorithm. This is because the A* algorithm has a good balance between optimality and efficiency which makes it able to handle large and dynamic virtual environments [27]. For example, the A* algorithm is the algorithm used by the Unity game engine for their AI navigation system.

3. METHOD

This research involved the creation of a virtual exhibition application using virtual reality technologies. The first step in the development of this application was the carrying out of a literature study to find information on topics relevant to the research. The topics explored in the literature study were virtual exhibitions, virtual reality, non-player characters and pathfinding. The information obtained was then used to help direct the research.

The application was then designed through the use of flowcharts. Flowcharts were mainly used to design how the application and its features will function, as well as the ways users will interact with them. Five flowcharts were made to help design the application. These are the main application flowchart, main gate flowchart, choose category flowchart, car search flowchart and the non-player character flowchart.

The main application flowchart explains the flow of the application and how the user will use the application. It details which features of the application that the user can interact with and in what order. This includes the main gate, choose category and car search features. The main application flowchart can be seen in Figure 1.

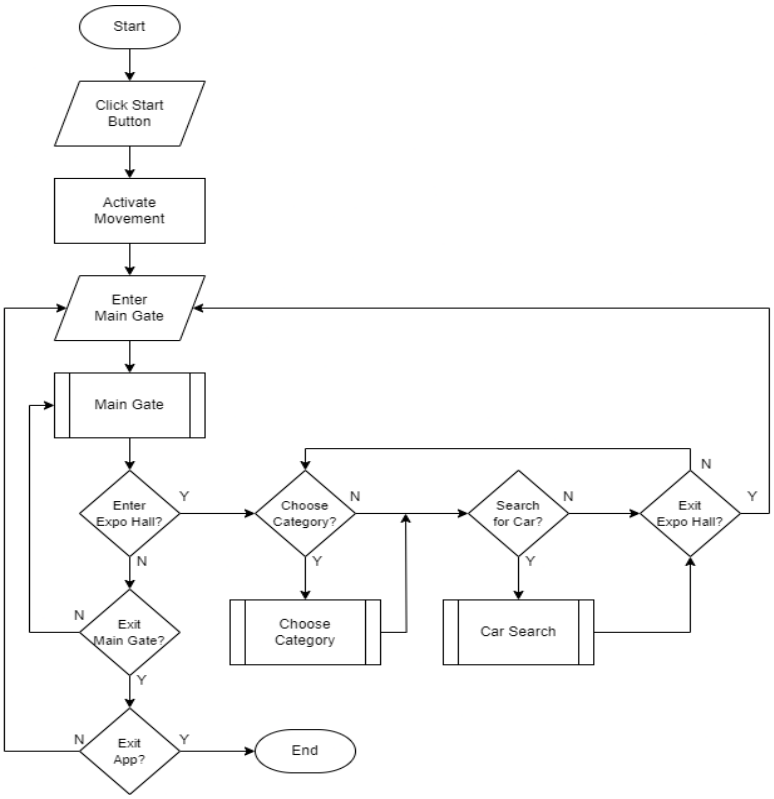

Figure 1. Main application flowchart

The main gate flowchart explains what the user can do in the main gate section of the application. The main purpose of the main gate is for users to choose which exhibition they want to visit. Once an exhibition is chosen, the application will then check its availability to see if it can be visited or not. Another feature of the main gate is the credits section. This is where users can see a list of all the assets that were used in the making of the application. The main gate flowchart can be seen in Figure 2.

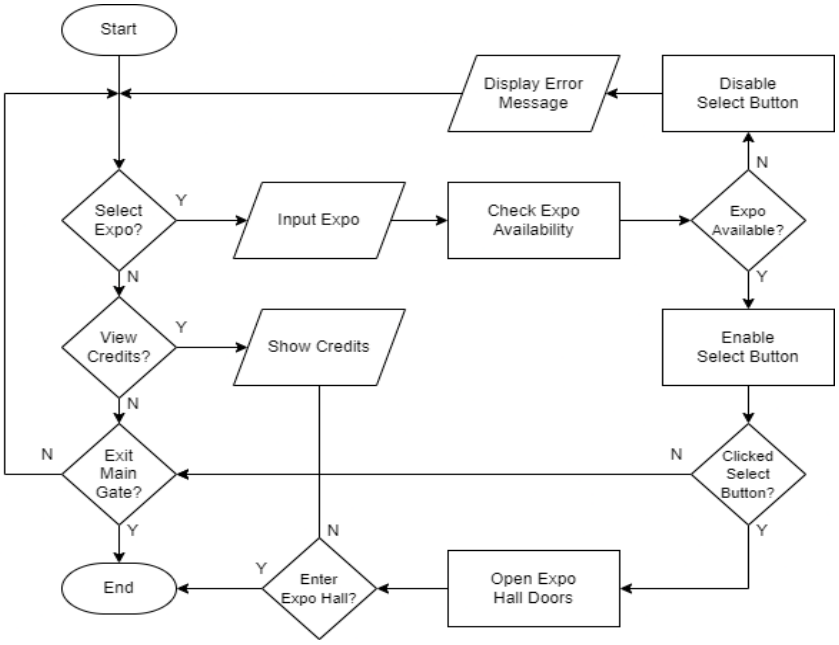

Figure 2. Main gate flowchart

The choose category flowchart was made for the category selection feature. This is where users can change the products being displayed in the exhibition hall. Each category, which in this case are countries, will have a number of products associated with them. When a category is selected, the exhibition hall will display its products on the display stands. The products in a category will be split into different halls depending on the number of display stands in the exhibition. For example, a category containing 13 products will be split into a first hall containing the first 8 products and a second hall containing the remaining 5 products. Users can then press a previous button and a next button to alternate between the halls in a category. The choose category flowchart can be seen in Figure 3.

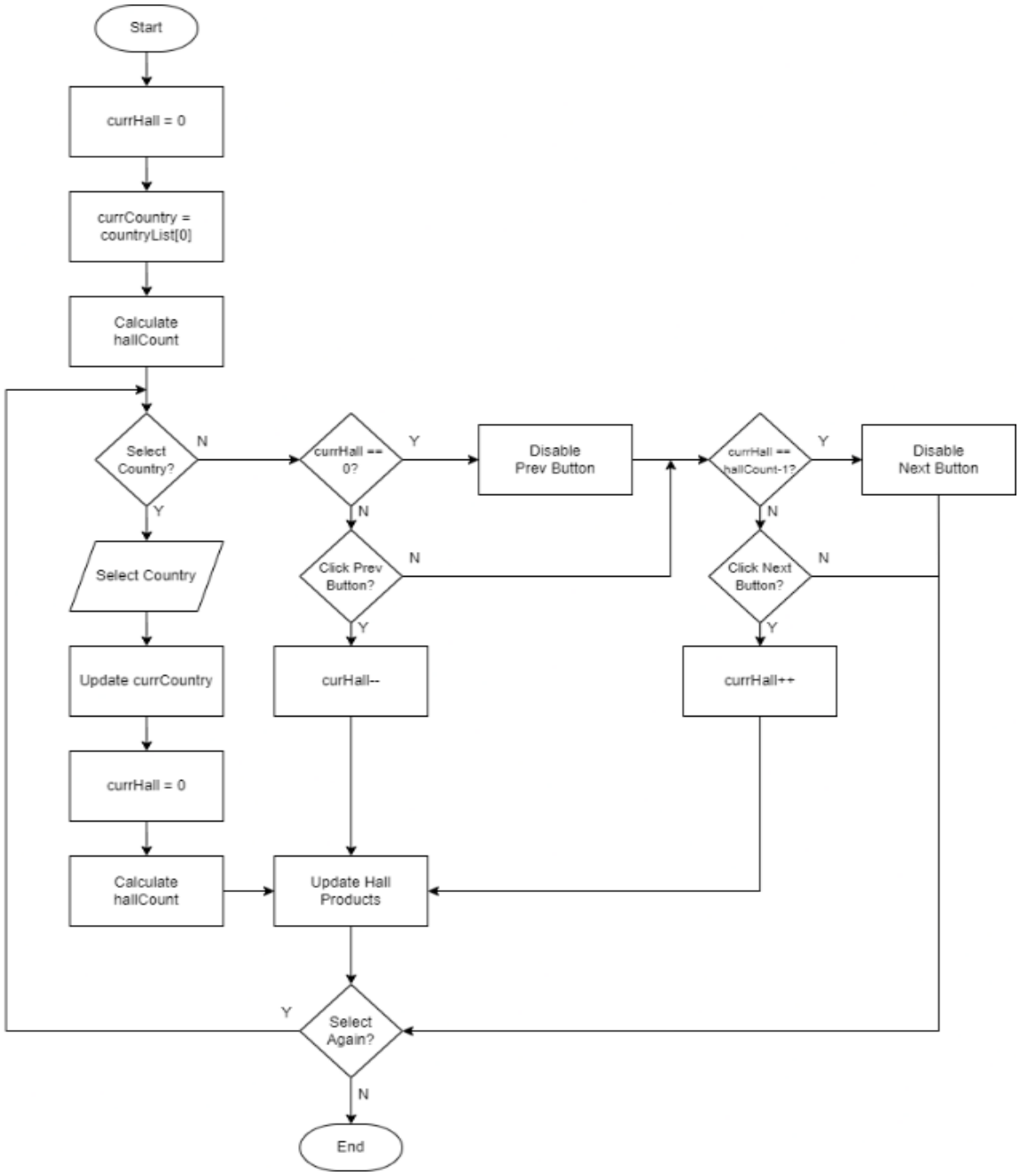

Figure 3. Choose category flowchart

The car search flowchart was used to map out how players can search for a specific product that they may be looking for. Users can search for a certain product by using two different dropdown lists. The first list is used to select the brand that the product belongs to. Choosing a brand from this list will alter the

contents of the second dropdown list to all the products belonging to the selected brand. Users can then select whichever product they want from the second dropdown to view it. The car search flowchart can be seen in Figure 4.

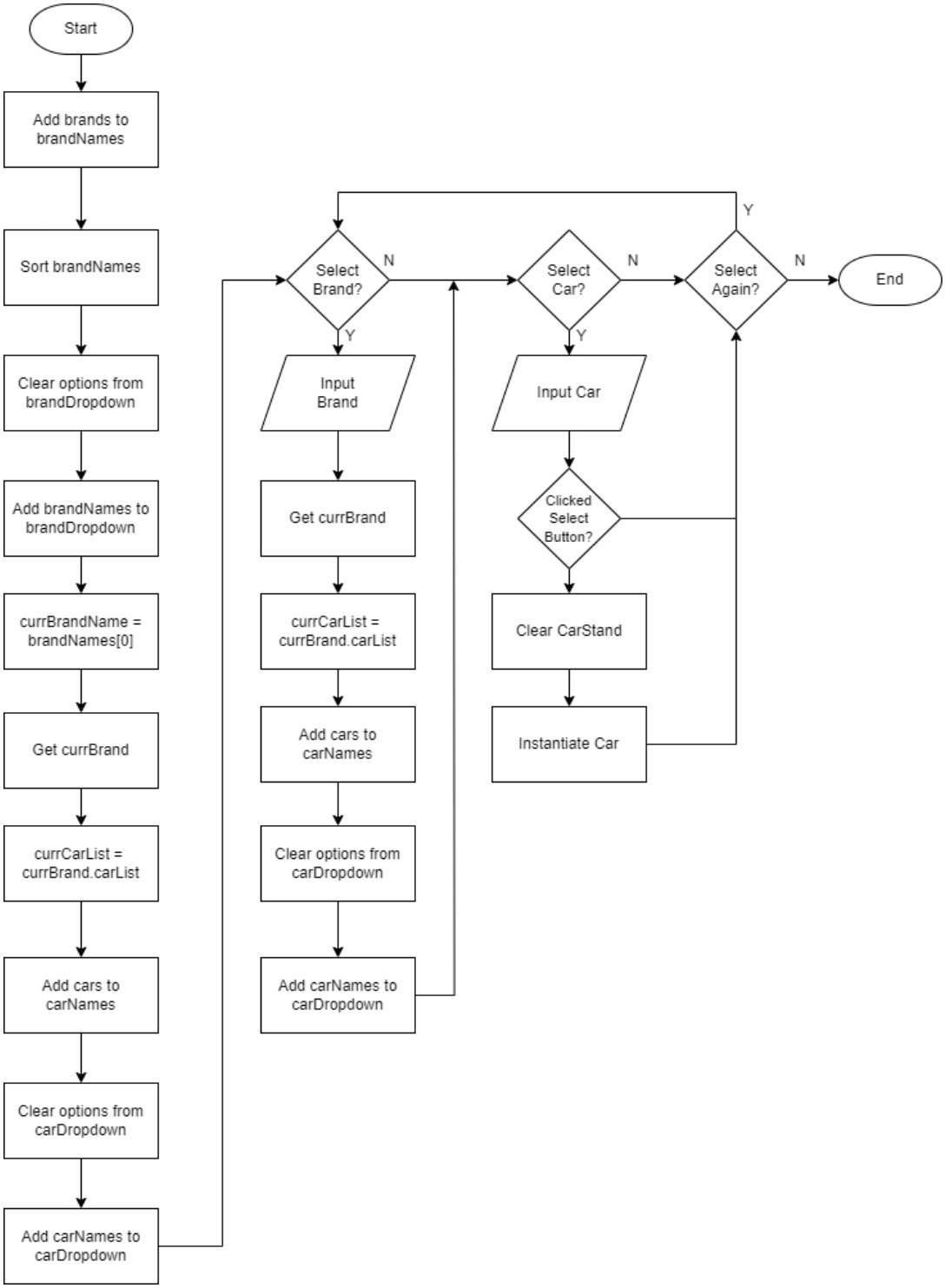

Figure 4. Car search flowchart

The non-player character flowchart was made to model the behavior of non-player characters in the application. It mainly concerns the way that they navigate around the virtual environment. Pre-determined

waypoints are set around the virtual application beforehand. The non-player character can then choose one of these waypoints randomly and start walking towards it. The distance between the non-player character and its destination will constantly be checked. If the distance is sufficiently small then the non-player character has reached its destination and will then choose a new one randomly. The non-player character flowchart can be seen in Figure 5.

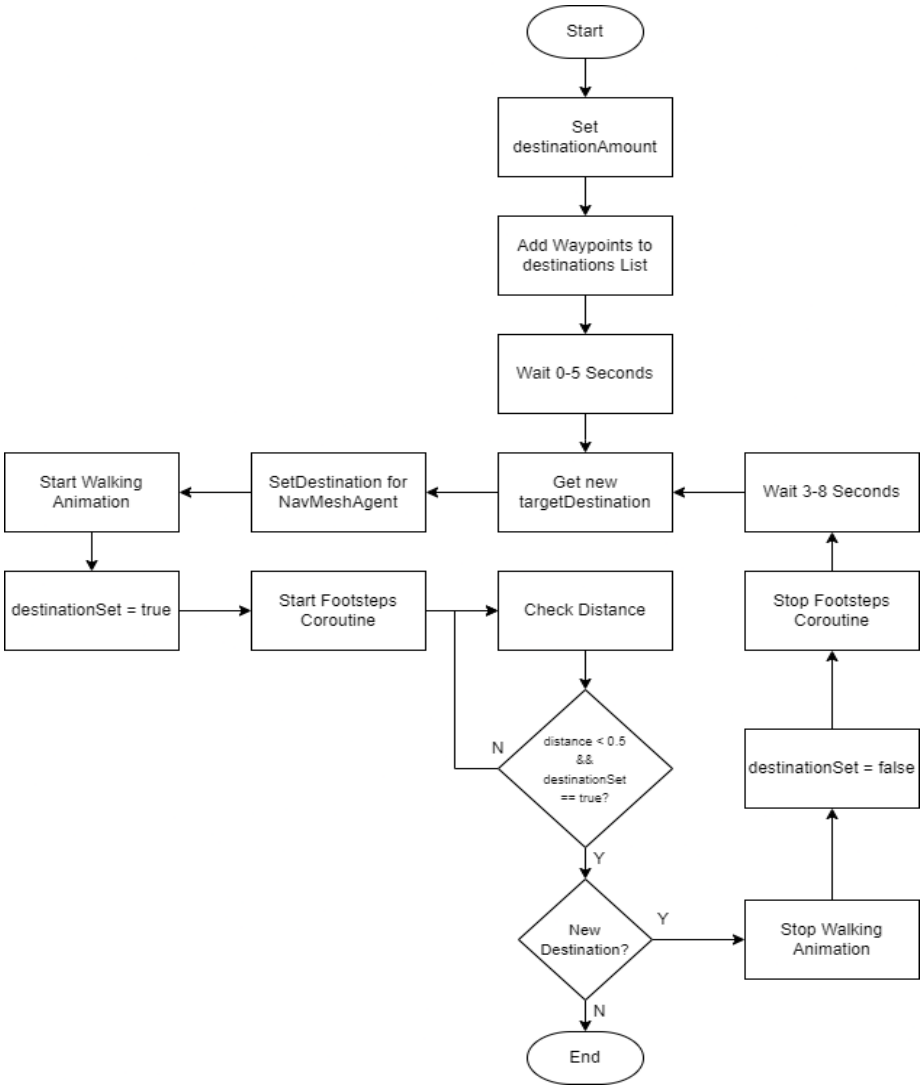

Figure 5. Non-player character flowchart

Application development was later carried out using the unity game engine. Development involves implementing the designs that have been made. Various unity packages were used in the making of the application. The Unity XR Toolkit package was used to create the movement system allowing players to walk, turn and teleport. It was also used to create the interaction system which allowed players to interact with objects and UI using the virtual reality controllers. Other packages such as Probuilder and Terrain tools were used to create the virtual environment of the application.

The application that was developed took the form of a 3D virtual environment. Users can navigate this virtual space and interact with the objects within it. The application required the use of virtual reality hardware in order to be used. The Oculus Rift headset and controllers were used for development and testing purposes in this research. The virtual reality headset was used in order to display the application to users and to rotate the in-game first-person camera. The controllers on the other hand were used by users to navigate and move around in the virtual environment of the application.

Evaluation was carried out by having users try the application directly using virtual reality hardware such as headsets and controllers. A brief explanation was be given regarding the application and how to use the hardware. Users will then use the application and try all the features on it. Documentation of the testing process carried out by users can be seen in Figure 6. After users have finished trying the application, they will fill out a questionnaire to provide their level of satisfaction with the application. Testing and evaluation was carried out by a total of 18 university students. This number is sufficient to be able to find at least 90% of the problems that may arise and to find problems related to the design, navigation, function and purpose of the application [28], [29].

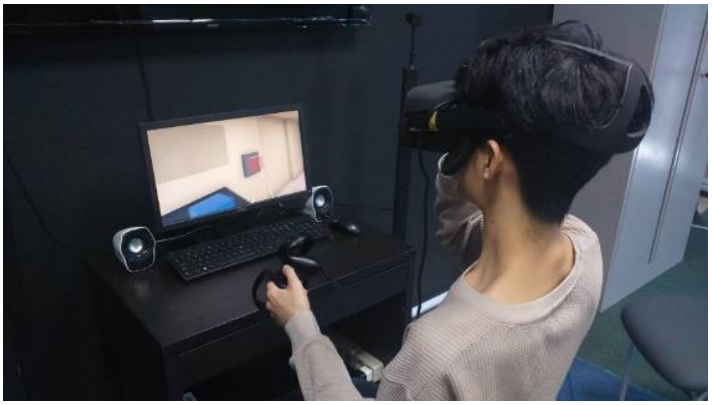

Figure 6. User testing the application

4. RESULTS AND DISCUSSION

4.1. Development results

This research has succeeded in building a virtual exhibition system using virtual technology. Application development was carried out using the Unity game engine. The application created has several main features, namely a movement and interaction system, exhibition features, an audio system, and non-player characters.

The movement and interaction system is how users can interact with the virtual world that has been created in the application. The movement system in the application is what allows users to traverse the virtual environment. Meanwhile, the interaction system facilitates users in interacting, influencing and obtaining information from the application. Because the application is built based on virtual reality technology, users will use a special controller as the main way to enter input into the application.

There are several different methods that can be used to move within the application. The left-hand controller functions to move forwards and backwards. To rotate left and right, users can use the right-hand controller or the virtual reality headset. Apart from that, the right-hand controller can also be used to teleport where users can adjust their position and rotation instantly. Figure 7 shows the use of the teleportation system in the application.

Figure 7. The teleportation feature

There are also several ways in which users can interact with objects in the application. Interaction is mainly carried out using the left and right controllers which act as the user's hands. The desired interaction with an object can be done directly, such as holding the object in a user's hand. Users can also use a ray coming out of their hands to interact with objects and the UI. This can be seen in Figure 8. Interaction with objects uses the grip button on the controller while interaction with the UI uses trigger button.

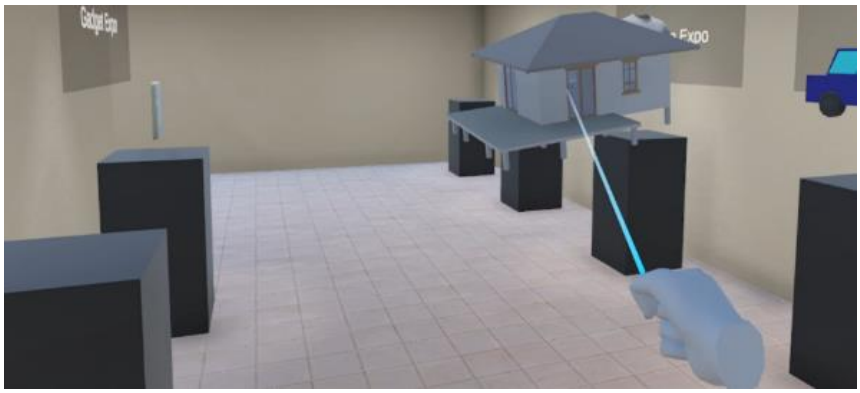

Figure 8. Interacting with objects using a ray

The exhibition features discussed are features that can be used by users in virtual exhibitions on the application. The features created are the result of implementing the designs produced at the design stage. They cover how a user can use the application as a virtual exhibition. Included in this is how users can select the exhibition they want, view the desired product, and view information about a product.

The exhibition selection feature is a way for users to select the exhibitions they want to visit. This is done at the main gate section of the exhibition building. The selection is made by taking an object that represents an exhibition and placing it on the selection table. If the selected exhibition can be visited then the button next to the entrance will turn green. If the exhibition cannot be visited then the button will turn red and an error message will appear once the button is pressed. This can be seen in Figure 9. Only the car exhibition can be visited at this time.

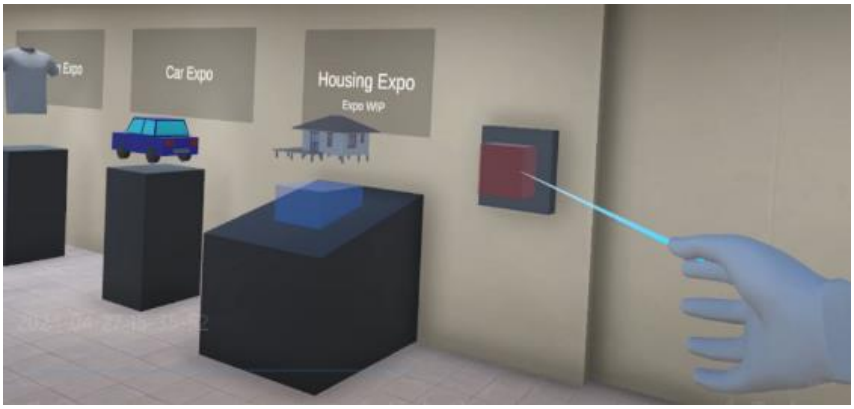

Figure 9. Choosing an exhibition that is not available

The product selection feature is how users can search for the products they want at the exhibition. Users can do this by changing the contents of the exhibition space. The products at the exhibition are divided into several categories that users can choose from. Each category will then have several rooms that can be selected to change the contents of the exhibition space. In the car exhibition, the cars are divided based on their country of origin. After selecting a category, users can select the room or hall they want to view. With this, the contents of the exhibition room will change to show the cars in the selected hall. The category selection table can be seen in Figure 10.

Selection can also be done individually with the product search feature which can be seen in Figure 11. With this, users can search for products more specifically. In the car exhibition, the search feature functions by using a dropdown list containing all car brands in the application. Users can then select a desired brand. This action will add all products from that brand to the second dropdown list. Users can then select the products they want from the second dropdown list to make them appear.

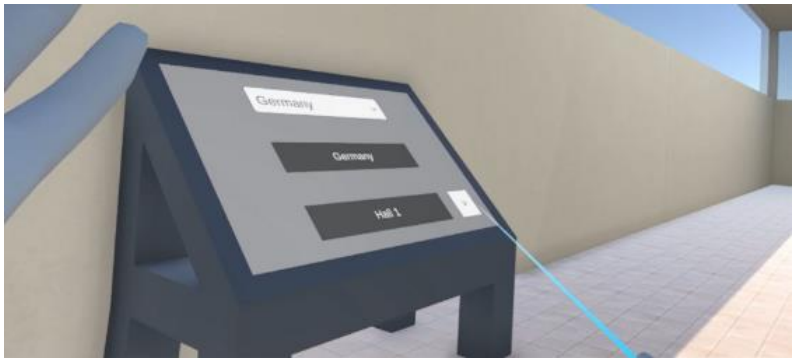

Figure 10. Category selection table

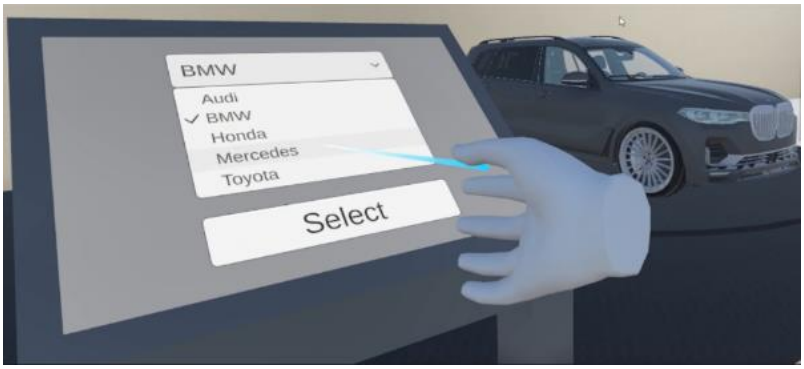

Figure 11. Product search feature

Then there is the feature in the exhibition that function to provide information about a product. This feature facilitates users in finding information about the products they are interested in. At the car exhibition, information about a car is shown on a screen on the stand occupied by the car. The screen shows information about the car such as its name, dimensions, and price. Users can press buttons at the bottom of the panel to change the information displayed. The information screen display can be seen in Figure 12.

Figure 12. Product information feature

An audio system was developed in the application to make the application produce sound when used. The sound in the application comes from objects in the environment. Sounds can be played when the user interacts with an object. For example, there will be a sound when the user picks up and releases an object. There are also sounds that play continuously such as the music in an exhibition hall.

The application uses two different types of audios, namely 2D audio and 3D audio. 2D audio is audio that is always played at the same volume. An example of using 2D audio in an application is for UI such as buttons and dropdown lists. 3D audio is audio that is played at a dynamic volume. The volume of 3D audio depends on the distance between the sound source and the user's position in the environment. 3D audio is used for things like the music in the exhibition hall and the sound of footsteps belonging to non-player characters.

The non-player character or NPC feature in the application refers to characters who are controlled by the user. These characters are controlled by the application that will give instructions to regulate their behavior. With this, the movements of non-player characters are carried out independently without input from the user. Non-player characters are used in the app as a way to simulate the presence of other visitors at the exhibition.

Navigation by non-player characters is carried out using the AI navigation system provided by Unity. In this system, a NavMesh is used to mark areas that can be traveled by non-player characters. The shape of NavMesh can be modified using other components such as NavMeshObstacle and NavMeshVolumeModifier. The non-player character can then plan a path to a destination located in the NavMesh. Several destination points are spread across the exhibition room and are chosen by non-player characters at random. All this can be seen in Figure 13 where the blue area is the NavMesh and the yellow dots are the destination points. Once selected, the non-player character will start walking towards that point. A new point will then be selected once the non-player character successfully reaches their destination.

Figure 13. Navigation system for non-player characters

4.2. Analysis of evaluation results

Evaluation results from the questionnaire that was filled out by users were analyses by calculating the mean values. The mean of the answers given by users is calculated by dividing the total score of all answers by the number of answers. To calculate the total score for an answer, all the values given by users will be added up based on their respective value weights. The final score is then calculated by adding up the means of each answer and dividing it by the number of answers in the questionnaire. The results of the user evaluation can be seen in Table 1.

The total score is calculated using the following formula:

$$TotalScore = (answer1Amount * 1) + (answer2Amount * 2) + (answer3Amount * 3) + (answer4Amount * 4) + (answer5Amount * 5)$$

The mean is calculated using the following formula:

$$Mean = \frac{Total\ Score}{Number\ of\ Respondents}$$

The final score is calculated using the following formula:

$$Final\ Score = \frac{\Sigma Mean}{Number\ of\ Questions}$$

Table 1. User evaluation results

Questions	Number of responses					Mean
	1	2	3	4	5	
Is the visual quality of the application good?	0	0	1	8	9	88.9%
Is the quality of the movement system in the application good?	0	0	0	3	15	96.7%
Are the interactions with objects and UI in the application good?	0	1	0	7	10	88.9%
Is the audio quality of the application good?	0	0	2	2	14	93.3%
Is the quality of the content in the application good?	0	0	1	4	13	93.3%
Is the information provided on products informative?	0	0	0	5	13	94.4%
Is the application intuitive and easy to use?	0	0	1	6	11	91.1%
Is the experience of using the application immersive?	0	0	1	4	13	93.3%
As a whole, are you satisfied with the application?	0	0	0	5	13	94.4%
Final Score						92.7%

With this, it can be interpreted that the virtual exhibition that was made had been received well by those who tried it. This is supported by a high final score of 92.7%. From the evaluation results it can also be seen that the movement system gets the highest score. This suggests that movement within the application feels smooth and natural for users.

Another key result to point out is the high levels of immersion reported by users. The immersiveness of the application received a mean score of 93.3%, with many users giving it the highest possible score. High user satisfaction with the navigation and immersion of the application strengthens the idea that virtual reality can be used to make users feel as if they are visiting a real exhibition.

The results of this research differed from those of the virtual museum tour that had been previously discussed. The application that has been made performs better in terms of interactivity and immersion. This could come down to the less restrictive methods of navigation used as well as the use of virtual reality technology. With these results it can be said that this research has done well in creating a well-functioning virtual exhibition application which implements virtual reality technology and in measuring user satisfaction towards the application. The study is limited however in the users that were collected for evaluation purposes. Only 18 users were able to be found for this research. And, there is a lack of diversity in the types of users with them all being university students within the same age group.

This research aimed to design and build a virtual exhibition system using virtual reality technology and to measure the level of user satisfaction towards the virtual exhibition application. With the carrying out of this research, user sentiments towards attending virtual exhibitions using virtual reality can be examined. Judging by the results, it would appear that users are open and willing to the idea. There are still questions to be held about the viability of hosting virtual exhibitions in this manner as this research only focused on the visitor side of things. How companies and brands feel about participating in these virtual exhibitions and whether the exhibitions can perform as well as conventional exhibitions still remain unanswered.

5. CONCLUSION

This research has been successful in designing building a virtual exhibition system using virtual reality technology. After testing with 18 users using the user acceptance test method and Likert scale, the user satisfaction level was found to be 92.7%, which shows that users are very satisfied with the application that was built. Based on this value, it can be interpreted that users generally accept that the system has been created well. These results support the feasibility of using the virtual exhibition system based on virtual reality technology that has been produced. This provides justification to any interested in carrying out such exhibitions. The virtual exhibition that was produced also performed better in terms of immersion and navigation compared to other exhibitions which do not use virtual reality. This suggests that the implementation of virtual reality technologies played a role in enhancing the user experience and that it could perhaps be applied to enhance other virtual experiences. To further test the viability of virtual exhibitions using virtual reality, more research can be done regarding their performance for the businesses who decide to take part in them.

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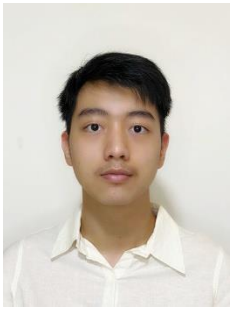

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