Application Design and Implementation for the Automotive Industry with Virtual Reality

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ABSTRACT

The concept of "Virtual Reality" has entered our lives by adding virtual reality glasses to the computers, smartphones, or tablets that we frequently use with the developing technology day by day. Virtual reality includes the virtual world and three-dimensional virtual objects created in the computer environment. Virtual Reality technology aims to enable people to interact with objects by immersing them in the virtual world through equipment (VR glasses, hand controls, treadmills, etc.). This technology can be used in education, health, shopping, etc. used, in many fields. In this paper, virtual reality technology was used in an automobile store application. The study aims to enable people to read the necessary information about the selected automobile by choosing a car and color. Users will be able to visit and interact with this auto shop with virtual reality equipment in their environment. The 3D models required for the study were made with the Blender program, the software was made with the Unity3D game engine, and the application was developed. The application was tested with the participation of 26 people. As a result, the feedback received from users has been positive. It is thought that the study will be developed and contribute to the literature in different ways.

Keywords:
3D modeling; Blender; Automobile; Virtual reality; Unity3D

INTRODUCTION

The era we live in is a period in which the internet and computer are at the center of our lives. Digital applications are increasing day by, day and accordingly, people's communication styles are changing [1]. These digital applications have started to take place in human life in a wide framework. With the widespread use of smart phones, the internet, and personal computers, digital applications have greatly increased [2]. Human beings have searched for various ways to process and present information with computers and have revealed different concepts. One of these concepts is the concept of "virtual reality". The concept of virtual reality can be briefly defined as the "reconstruction of reality".

Virtual environments offer a new "reality" beyond the current order and rules by going beyond what is considered normal, normal and ordinary. This presented reality makes it possible to look at the usual world and rules with a new perspective and to offer short and effective solutions to problems in many fields [3].

With Virtual Reality, a completely virtual image is projected to the user. Virtual reality adds a different method to the way people interact with the environment and adds a different perspective to the phenomenon called reality [4]. VR technology presents a 3D, simulated and controllable virtual world to the users as if it were real [5]. VR glasses enable users to interact with the virtual world. In this way, people's imaginations expand and offer a new field in their interaction with the environment.

In short, VR (Virtual Reality) is a simulation in which computers are used to create realistic worlds, making people feel like they are a part of this created virtual world, and changing in real-time according to the user's inputs [6]. VR, which enables users to take an active role in the computer-generated 3D world, can isolate users from the real world and immerse them in the virtual world [7]. VR applications can be used to go to places that are difficult to go, and can be used in jobs that are almost impossible to do and may have dangero-

us results. In addition, thanks to these applications, it can be used both in perceiving and visualizing abstract concepts and in a wide variety of fields. Simulations of real environments and objects can be made easy thanks to the computer technology developing day by day [8].

Today, when the concept of virtual reality in the automotive industry is evaluated both as a customer and an employee, Z and Y generations come to mind. Even though many countries, especially developed countries, are struggling with the decreasing population, Generation Z is currently the largest generation in the world [9].

Considering that 32% of the world 's population consists of the Z generation, it is seen that VR technology will be benefited from the automotive sector in purchasing and corporate organizations. In the automobile industry, which has the majority of the consumer market, due to the globalizing market and the accompanying competition; businesses are faced with new problems in terms of quality, cost and time [10].

Showroom, etc., designed by automobile manufacturers or dealers. In places, customers can experience virtual reality. Virtual reality technology is also a very important technology in automobile production. For example, people who will work on the production line can be trained in a virtual environment with VR glasses. A virtual environment and VR glasses designed for this training will be sufficient. Manufacturers can save time and cost and complete the training without stopping their production lines.

SEAT, one of the automobile manufacturers, has benefited from virtual reality technology in its design. Virtual reality technology has saved time in production, reduced the margin of error, and reduced the prototype production time by 30% [11]. This has led to an increase in the quality of the car and a decrease in the final price.

Another automobile manufacturer, Toyota, launched the CHR model with virtual reality technology. It has allowed customers to digitally customize and explore the vehicle in VR [12]. TürkTraktör, from the Turkish automotive industry, has become one of the companies that provide training in virtual reality. After the training, it was observed that human-induced errors decreased by 89%, assembly skills increased by 28%, and the training had a positive effect of 81% on learning. With the Co-Creation program, Ford company provides the opportunity to work by bringing its engineers from different parts of the world together in the VR world. Here designers can create 3D models in real-time. This way, jobs that take months are reduced to as little as 40 hours [13].

Ebnali et al. (2021) conducted a study on autonomous vehicles. In the study, a VR application was carried out for confidence in autonomous vehicles and driving training. According to the results obtained, the application can be used for automatic driving training in car rental centers and dealers [14].

In their study, Tai et al. (2022) aimed to provide technical students with car detailing training in VR. The developed application was tested with the participation of 143 students. As a result of the studies, it was observed that the education designed in VR was positive [15].

Virtual reality, which has a wide usage area, is also used in 3D design, smart control, pattern detection, image processing, networking, etc. It includes a lot of high technology. VR technology, which has different examples in the literature, is used in many sectors such as education, engineering, architectural design, transportation, military, medicine and entertainment.

This study, an automobile showroom application was carried out by using virtual reality technology. Blender program was used in the design and Unity3D game engine was used in the software. In the study, the users were provided to read the information about the selected vehicle as well as the model and color selection processes related to the vehicle. Users will be able to visit the garden and showroom. The developed application was tested with the participation of twenty-six people. As a result of the tests, the application was found to be open to development, innovative and useful.

MATERIALS AND METHODS

This study has developed an application for the automotive industry using virtual reality technology. The virtual reality environment, the necessary 3D objects, and the user interface have been created, and all the elements have been integrated into the Unity3D game engine. Here, with the help of the Visual Studio program, the necessary coding was done using the C# programming language. Finally, this application, developed in a computer environment, was transferred to the Oculus Quest-2 virtual reality glasses. The construction phases of the study are as follows:

1. Blender: Virtual world and modeling of 3D objects

2. Inkscape: Creation of the user interface

3. Unity3D: Creating the application by making the necessary software

4. Oculus Quest-2: Testing the app developed on the VR headset

Blender

Which program should be used in the 3D design is decided in line with the needs of the study. Today, many three-dimensional object modeling programs such as Blender, 3DsMax, Maya, ZBrush, and Cinema4D.

Blender is an open source and free platform. It has many features, such as 3D modeling, animation, and texture creation. The program is developed by the Blender Foundation, founded in 2002. The program, which continues to be developed by high-level users, can be used by animators to professionals [16].

There are no limits to design in virtual reality technology. Factors such as cost, durability, and gravity do not matter. As long as the hardware and software are sufficient, there is no end to what can be done. Every imagined and designed object can be used in the virtual reality world. In addition to all these, the sense of reality is also important. Since the sense of reality is important, the interior and exterior areas of the automobile store were designed with the real world in mind.

Solid mode drawings of the designed interior and exterior are shown in Fig. 1 and Fig. 2. Modeling was done using vertex, edge and face components. These components are called polygons. It is important to keep the number of polygons low not to force the system while modeling.
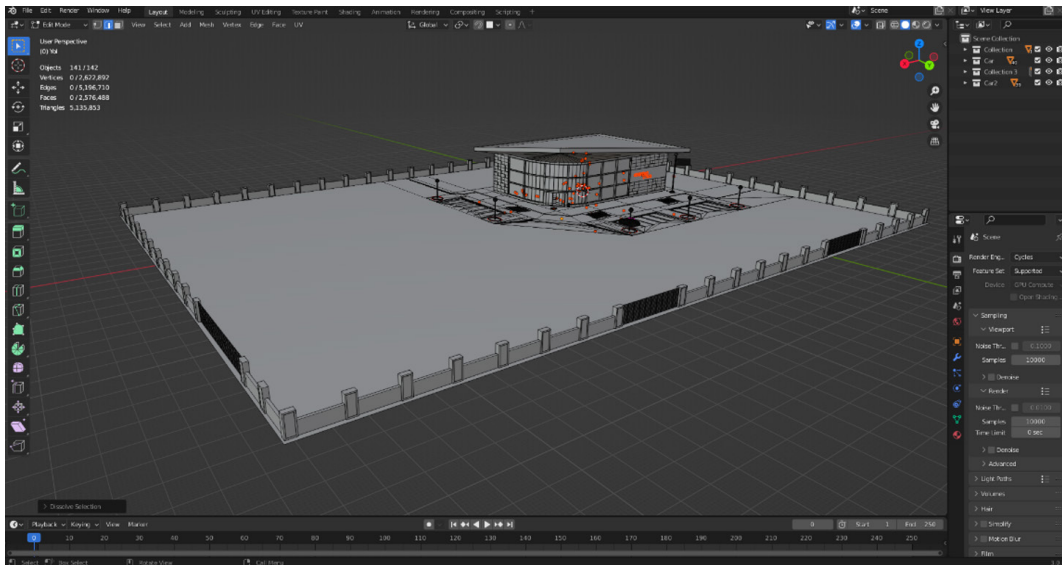

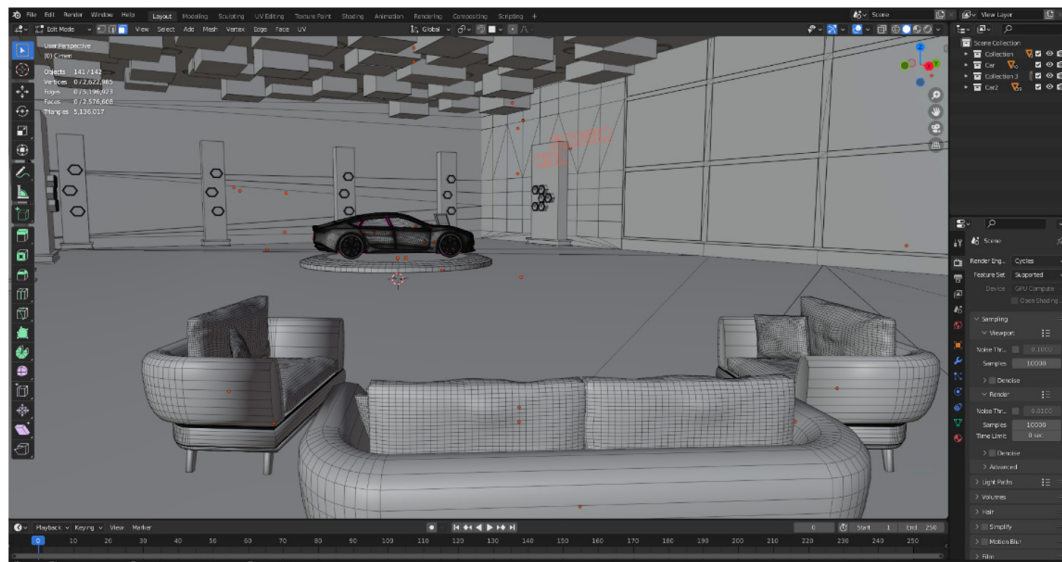**Figure 1.** Exterior Drawing of Auto Shop.

Figure 2. Interior Drawing of Auto Shop.

Figure 3. Material and Texture.

Figure 4. View of the Interior of the Store.

The walls surrounding the garden, street lamps, car parks, automobiles, shops, and pavements are objects designed to feel lifelike. When looking at the interior, various lightings, guest seats, the platform on which the cars are located, and the information screen can be seen. These 3D objects are designed to give people a sense of reality. Users can perform actions such as walking around the garden, examining the parked car, walking around the store, sitting on the sofa, and watching the surroundings.

In addition to 3D modeling, material and texture assignment processes are also performed in the Blender program. Looking at Fig. 3, the Material mode image of the store's exterior is seen. Street slides, parked yellow cars, and building walls were colored by adding materials. The texture is used in floor and pavement designs. The reason

for using texture in these objects is to increase the sense of reality. Used texture, Color Map, Ambient Occlusion, Normal Map, and Height consists of map channels. The texture channels used to give the photos a three-dimensional effect. Another benefit of using textures is that it ensures that the number of polygons in the design is low. For example, modeling small stones instead of the stone texture used on the ground increases the number of polygons. A similar situation can be said for the pavement object.

In Fig. 4 and Fig. 5, there are visuals of the coloration and lighting of the store's interior design. While mostly color material is used, the texture is used on the seats. The purpose of this is to make users feel the fabric's texture. The lighting process is created with emission-type material. With the emission material, the color of the objects is

Figure 5. Interior Lighting of the Store.

made bright and used as light. The lights used in Blender cannot be transferred to the Unity3D platform. For this reason, emission type material is preferred. In cases where the light is insufficient, adding light can be done in the Unity3D game engine.

Inkscape

Inkscape is a graphic editing and designing program. With this program, illustrations, logos, charts, etc. Many complex graphics operations can be performed. Like Blender, Inkscape is a free program available to users.

In the study, the Inkscape program was used to design the user interface. In Unity3D, buttons, text, images, etc. Canvas is used to add items to the system. The designed interface is transferred in Canvas. Canvas provides the ability to interact in VR. Fig. 6 shows the user interface designed in the Inkscape program.

Inkscape program, two car models, eight colors, "i" and "x" buttons were designed. Users can choose which car mo-
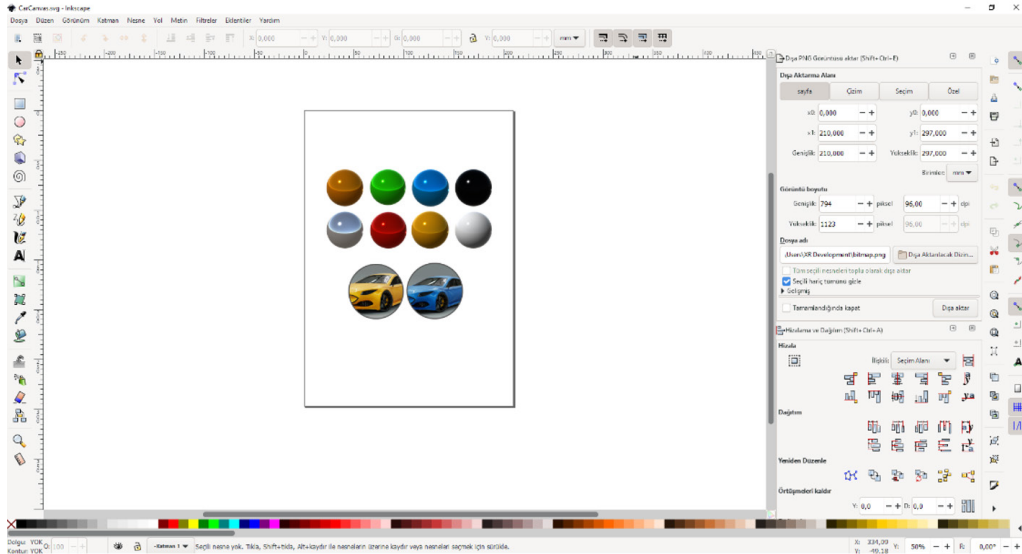

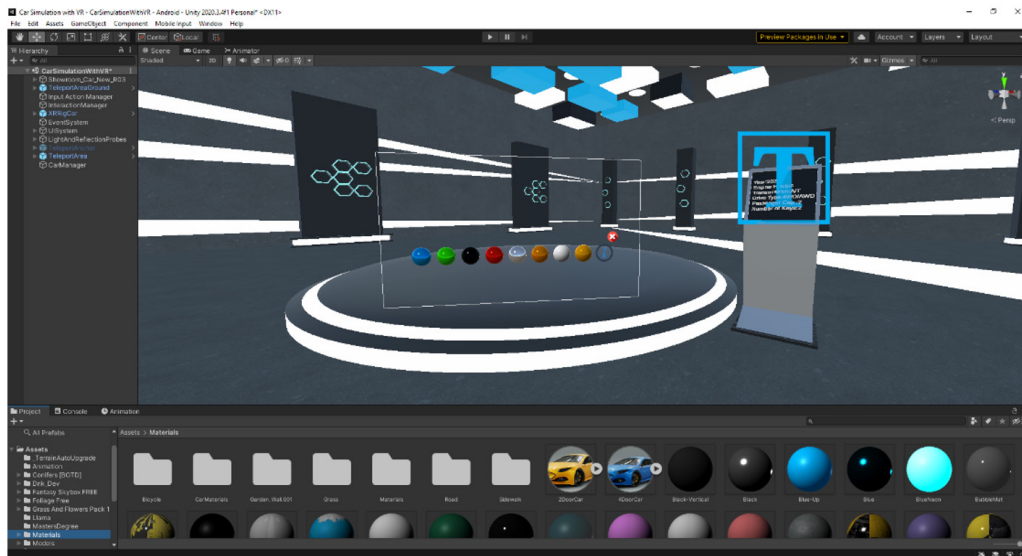**Figure 6.** User Interface Designed in Inkscape Program.

Figure 7. Designing Interface Buttons Used in Unity3D.

Figure 8. Interior View of Auto Shop on Unity3D Platform.

del they want and see the car in different colors thanks to eight color buttons. Here, the "i" button opens the information screen, while the "x" button provides the exit from the menu. Fig. 7 shows the Canvas used in Unity 3D. There is an information button at the end of the color buttons and an exit button above it. Information about the car is shown on the information display next to the scene.

Unity3D Game Engine

Unity3D is a highly productive platform with 3D animation and interactive content. Before starting coding in Unity3D, design and analysis are required. It behaves according to the script added to the object. That's why coding is important. Unity editor is the interface used for game project development. One of the most important features of Unity3D is that it is compatible with different platforms (Mac, PC, iOS, Web, Android, Xbox, etc.) [17]. Unity3D and C# software languages, which are free for personal use, were used together in this study.

3D objects modeled with Blender are output in "fbx" format and used in the Unity3D platform. Fig. 8 shows the interior view of the virtual reality store imported to Unity3D and the interface of the Unity3D game engine.

The image of the exterior of the study is shown in Fig. 9. It is possible to change the materials used in Blender in Unity3D or to render all the materials in Unity3D. Some of the materials transferred from Blender in the study were revised in Unity3D. The goal here is to show that material creation can also be done in Unity3D.

The more users like the designed world in virtual reality, the more they enjoy it. Therefore, the sky and the environment where the designed store is located is important. In Unity3D, it is possible to design the external environment using HDRI images or Skybox. The sky and mountains visible in the study were created with HDRI images. Forest, sea, city, etc., of the 3D environment designed with HDRI images possible to appear in it. Not modeling such environmental environments does not tire the system by ensuring that the number of polygons is low.

Collider prevents users from passing through objects and going outside the simulation boundaries. It can be defined as the obstacle found in Box Collider Unity3D. For example, if Box Collider is not applied to the garden walls, users will pass to the other side of the wall and fall into the void. Users who fall into the void, that is, exit the simulation, have to log in again.
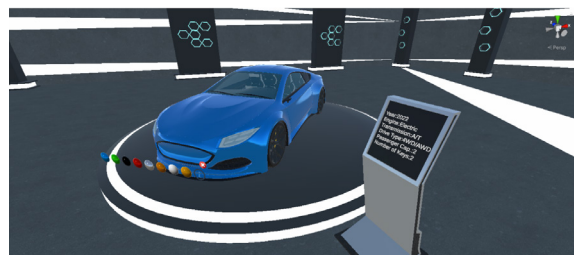

Figure 9. Exterior View of Auto Shop on Unity3D Platform.

Figure 10. Canvas Used for Implementation on Unity3D Platform.

Figure 11. Car Selection Codes.

Fig. 10 shows the "Canvas" structure and information screen on the Unity3D platform, which will enable users to interact. Canvas is the area where users will interact. This area makes car model selection, color changing, and information reading interactions.

In Fig. 11, the car selection script pseudocode is given. CarControlManager to avoid conflicts in different car selections script file has been created. Here, the files related to the selected car are displayed on the screen, and other car information is deleted from the screen. In this way, conflicts between different car information are prevented.

Fig. 12 shows the car color change script. pseudo Some of the codes are given. pseudo Code is defined as the writing of a code in expressions that everyone can understand, reminiscent of everyday speech. The Script file created in the Unity3D environment is named "ColorPicker". Initially, arrays and variables are defined. Array elements can be created in any number with external access. The interface, which was created as eight colors, was left open to be created with the desired number of colors. This software has been developed according to SOLID principles.

The SOLID principle is defined as the rules required for the software developed with Object Oriented Programming (OOP) to be flexible and suitable for development. Applications developed in line with this principle will certainly not be complicated [18]. The SOLID principle consists of 5 different principles;

1. single responsiveness Principle (Single Responsibility Principle)

2. Open/ Closed Principle (On/Off Principle)

3. Liskov Substitution Principle

4. interface segregation Principle (Interface Separation Principle)

Figure 12. Car Color Change Codes.

5. Dependency inversion Principle (Dependency Inversion Principle)

To the second principle, the Open / Closed principle, the software is left open to development. A separate function is used for each color. Each function is assigned a task. Thus, the first principle of SOLID principles, the single responsibility principle, was fulfilled. These script codes were loaded on the buttons and the necessary function assignments were made to the relevant buttons.

Oculus Quest-2

The Oculus Quest-2 is a head-mounted VR device developed by Oculus VR (Fig. 13). This device, released in 2019, can operate independently or connected to a computer [19]. The glasses have two controls that allow the user to interact. With these controls, users can perform tasks such as walking, teleporting, clicking buttons, and holding objects. There are joysticks, two buttons, and the selection and trigger buttons on the hand controls that can be defined as right and left hands.

Which was designed with the Blender program and developed in the Unity 3D game engine, was tested and used with the Oculus Quest-2 virtual reality glasses. To prepare the Oculus Quest-2 for use, the ground and safe area zones must be introduced. These processes allow users to use
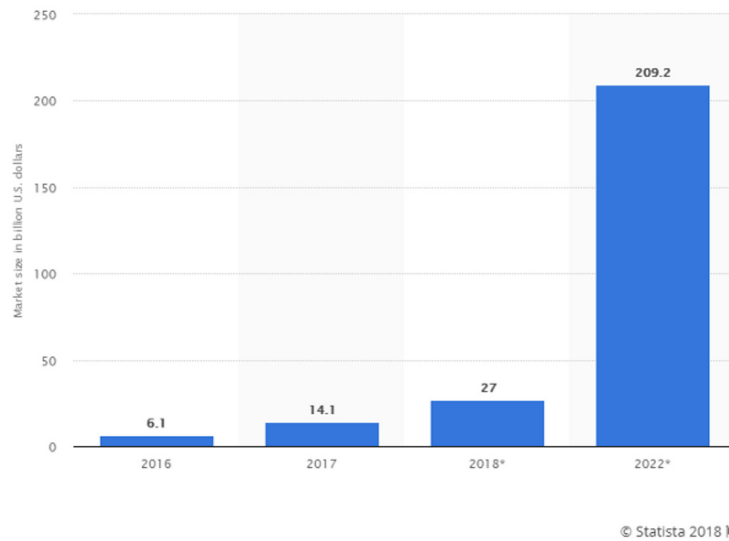

Figure 13. Oculus Quest-2.

Figure 14. Virtual Reality of Technology to the Years By Value (GFDS, 2020).

VR glasses safely. The area identification process is done through the controls after wearing the glasses. After these processes, the application is opened and used in VR glasses. With the interaction, users can navigate the virtual world more easily. In the study, turning left and right with the joystick on the hand control, forward teleportation and walking interaction is performed. The buttons on the Canvas interface can be used with the trigger on the back of the controller. In this way, people can select car, change colors, turn information on and off, and completely turn off the menu.

RESULTS AND DISCUSSION

This study presents an application developed for the automobile industry using virtual reality technology.

It is inevitable that virtual reality technology will increase its importance day by day and continue to develop. The world's largest research from organizations the one of Statista to the data according to (Fig. 14) virtual reality of technology value from 2016 to the present lots serious an increase showed. Virtual reality technology was 6.1 billion in 2016 dollar increased by 131% in 2017. It showed 14.1 billion dollars to its value reached. 27 billion in 2018, an increase of 91.5% dollar in 2022 if large an increase (674.8 %) showing 209.2 billion dollars to its value [20]. This also shows that people in recent years, virtual reality to technology large interest they hear. Virtual reality technology is a fun and useful technology where users can interact by making them feel like they are in the real world. This study, it is aimed to provide users with a realistic world experience.

VR glasses and equipment, start the simulation in the garden of the store (Fig. 15). Thanks to the remotes, people can walk around the garden and the store as they wish and interact with software. They can see two car models in the store and these cars in eight different colors.

Our movements, such as bending and straightening in real life, are also found in the virtual world. Therefore, sitting or standing actions are effective in simulation. For

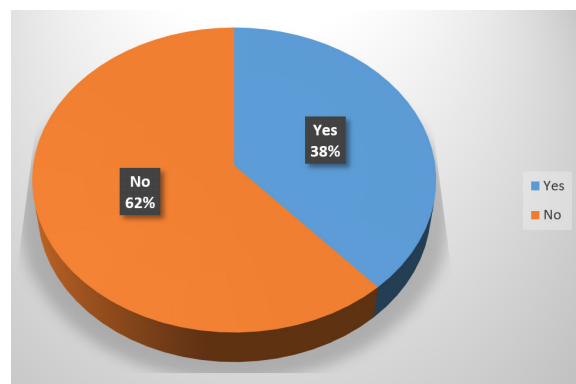**Figure 15.** Use of the Developed VR Application.

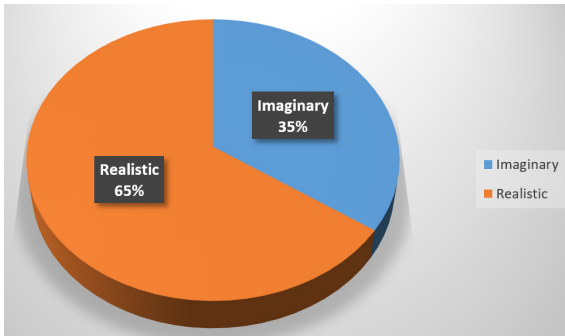**Figure 16.** "Have You Experienced VR Before?" Answers to the Question.

Figure 17. "How Would You Like The Design to be in VR?" Answers to the Question.

Figure 18. "How Often Do You Consider Using VR Applications?" Answers to the Question.

example, the user can see the interior design by leaning towards the car's window in the simulation, or when he sits on the seat, he experiences the feeling of being seated. Such features enable people to adapt to the virtual world more easily and increase the realism of the virtual world.

The study was tested by different people using the Oculus Quest-2 device. 26 people between the ages of 20-40 participated in the test. First of all, the participants were asked whether they had experienced VR before, and they were allowed to test the developed application. Fig. 16 contains data on the answers received. While 62% of the participants had not experienced VR before, 38% had VR experience. With the shrinking of VR technology hardware, it is a technology that has started to show itself in recent years. Despite this, it is seen that some of the users are acquainted with this technology.

In addition, the following questions were asked to the participants;

• "How would you like the design to be in VR?" Fig. 17 shows the answers to this question. Although the VR world has no boundaries, only 35% of the participants favored imaginary design. 65% of them stated that they wanted realistic design.

• "How often do you consider using VR apps?" Fig. 18 shows the answers to this question. The frequency of use of VR applications varies depending on the needs or curiosity of the users. Of 26 people, 42% stated that they intend to use VR applications several times a week, 27% once a week, 19% once a month, and 12% several times a year. It is thought that these rates will increase with the spread of VR applications. With the questions asked, the opinions of the participants about VR applications were learned. It is thought that these data will contribute to other studies.

In VR applications, the act of walking can be performed as teleportation or drifting. The walking action is done with the joystick on the control. Users have different attitudes about teleporting and walking by dragging. While no
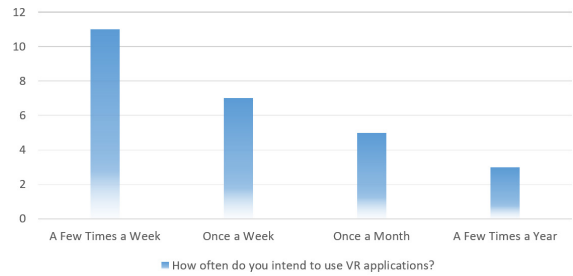
adverse events were experienced in walking with teleportation, there were some negative situations in the act of walking by dragging. Headache, dizziness and balance disorder are among them. 60% of the participants stated that they had headache, 28% had dizziness, and 12% had a balance disorder (Fig. 19). These situations affected the users for a short time. Based on these negativities, users were provided with two types of walking actions. People who want drag walking, that is, walking in real life, need to activate it in order to use it. For this, there is a "activate walking" button at the beginning of the simulation. When this button is not checked, teleportation will be provided.

Users have also experienced problems such as eye pain and watery eyes during long-term use of VR glasses. In addition, it has been observed that redness occurs around the eyes in proportion to the time the VR glasses are worn on the head. Despite all the negativities, users stated that the VR application was a different experience and had fun.

CONCLUSION

VR technology in the developed application made the created car store more realistic. Materials and textures used in 3D objects are other elements that add realism to the system. With all these elements, it aims to increase users sense of finding themselves in the virtual world. The steps to be followed in the use of the application developed on the Unity3D platform:

1. Uploading the application file to the VR glasses

2. Creating a safe area by attaching the VR glasses to the head

3. Using the application by opening it in glasses

The application has been tested with and without the VR glasses connected to the computer. As a result of the tests, no problems were found.

This study aims to enable users to visit the automobile store, choose car color and car type, and read information.
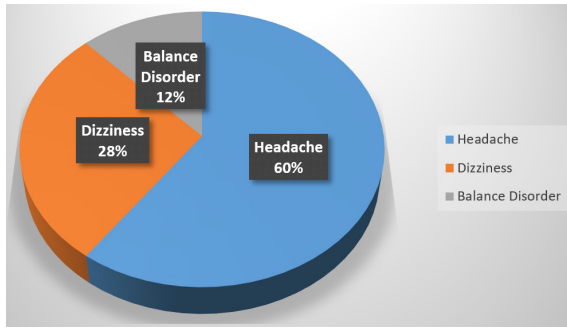
Figure 19. Adverse Situations in Walking with Drift.

Users can easily visit and interact with the Oculus Quest-2 VR glasses and controller.

It is possible to improve this study. More car models and different colors can be loaded into the system to increase diversity. In addition, customized cars can be created by making models for parts such as headlights, rims, and fenders. In order to increase the interaction in work, the hood, doors, and trunk can be opened/closed. A website can be loaded into the application, and you can connect to this site with one click.

Another development that can be done in the study is the e-commerce system. It can be turned into an e-commerce application by making the necessary research and additions. This will add a different dimension to online shopping. In addition, if it is combined with blockchain technology, it can be considered to create a much safer shopping environment.

The system can be made multiplayer so that more than one person can be present in the same environment. Thus, people who are far from each other have the opportunity to come together in a VR environment. Thanks to the multiplayer system, it is possible to organize meetings, entertainments, lectures, etc.

As a result, the users found the study useful and entertaining. Although there were problems such as dizziness, headache, watery eyes, etc. , the participants concluded that the VR world is a very different experience. Although some of the participants thought that the created car shop should be an imaginary design, most participants thought that seeing lifelike designs in VR creates a different sense of reality.

CONFLICT OF INTEREST

We have no conflicts of interest to disclose. All author to declare that they have no conflicts of interest.

AUTHOR CONTRIBUTION

The literature review, 3D modeling and software processes in this study were carried out by the 1st author. Necessary controls and arrangements were made by the 2nd author.

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