

A Serious Game Application for The Detection of Explosives

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Abstract— Detection, identification and on-site disposal of explosives is an important problem for personnel working in the defense industry today. With the increasing technology, it takes advantage of new cost-effective developments in the use of explosives by terrorists as well as the detection by the relevant teams. In addition, the training of the staff doing this task is a very important issue. In this study, the needs of the teams looking for explosives in the battlefield were evaluated and a serious game application was made for this purpose. Different scenarios that the teams may encounter with this application were considered and the scenes were designed according to this need. The military equipment and terrain to be used in the application are specially modeled for the specified missions and then transferred to the Unity game engine to provide a realistic gaming experience. In addition, the random distribution of explosives to the land, the transition between the levels and the preparation of a sample UI are shown in practice.

Keywords— Unity Game Engine, Serious Game, Detection of Explosives, Modeling

I. INTRODUCTION

Fighting with mines and improvised explosive device (IED) is one of the leading problems of defense today. Although there is much equipment for detecting and responding to explosives, the related units are faced with serious problems due to the difficulty of obtaining this equipment and the serious risks of the problem itself. It is very important to train and train the units that take part in this context. During the training, realistic situations should be created, and risks should be revealed. However, the diversity of the equipment used in the training of these personnel, the diversification of training areas and the necessity to create different scenarios complicate the implementation of these trainings. Therefore, different approaches are needed to train staff.

The aim of this research is to train personnel who fight explosives and neutralize mines and hand-made explosives. With the virtual environments to be created, it is required to model the situations that the personnel may encounter during their duty and to gain experience in related issues. It is aimed for the soldiers to learn the correct course of action by applying the intervention methods repeatedly.

With this study, units seeking explosives will have the opportunity to work on the regions where they will work and by using the application that supports this training at any time and place, they work. As a result of these trials and studies, it is evaluated that the training

level of the personnel will increase and the accident, incident or casualty that may occur will decrease.

In this context, In the second part of the study, the literature research on the subject will be mentioned; In the third chapter, modeling methods and processes in Unity will be mentioned, in the fourth chapter the stages of the application will be explained, in the fifth chapter, the result of the work will be explained and evaluated.

II. LITERATURE RESEARCH

Although there are many studies in the literature on the detection of landmines and handmade explosives and neutralization of these explosives, these studies are predominant on the technical methods used in the infrastructure of the equipment used to identify and neutralize explosives.

For example, in a 2008 study, magnetic anomaly method was used to identify mines. With this study, methods such as seismic acoustic detection, authorized radar systems, electromagnetic induction systems, infrared imaging were evaluated [1].

In addition to search technologies, some simulation applications have been developed to provide practical training to improve search methods. In this context, a mine exploration training simulator was introduced in 2017 [2].

Recording the terrorist incidents that took place in the Internal Security Operation since the 1990s is an important issue in establishing the infrastructure of the study. In this context, in a study conducted in 2016, the

terrorist events that took place in Turkey, pillaged, attacked the base area, attacks on police stations, handmade explosive and similar events are described statistically. In this study, terrorist incidents involving improvised explosive device took the second place with 352 [3].

On the other hand, the concept of gamification is very important in order to improve learning and to motivate individuals to this development. Gamification, which is a frequently encountered concept in digital games today, is now taken into consideration during the design of the game, and how the concepts are defined has a special importance [4].

Considering the concepts of virtual reality and serious acting, the contributions of these concepts to education and training are followed with great importance. Nowadays, the popularity of game-based learning is increasing day by day [5].

In this sense, serious games are distinguished from video games. Especially in serious games, it is important to present the environments, situations, and tasks to the user in a realistic way. For this reason, serious games can be reduced to many subheadings (Fig. 1) that are frequently encountered in real life such as health, social policies, strategic communication, human performance engineering, education, and assignment [6].

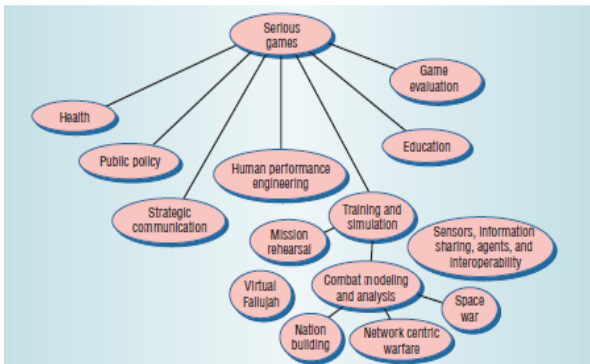


Fig. 1 Categorization of Serious Games

Serious games are often used to guide people through difficult and scary situations and to experience situations. In a study conducted in 2011, how people should make decisions in a difficult situation was explained with a computer-based design [7].

Generally, serious game studies are also used to show examples in dangerous and difficult moments. For example, a study that takes passengers to decide which exit to use in a sudden situation that they may encounter in the subway was carried out in Unity game engine in 2012 [8]. A similar study has been done on the horrible and unexpected events that passengers and officers may encounter on board. In this study conducted in 2015, virtual reality was also used, and it was explained how people should apply security procedures while facing these dangers [9].

With serious games, it is aimed not only to show people these situations and to experience them, but also to make the right decision. For example, in a study

conducted in 2014, an application was made that can guide people about how to behave in case of fire by using motion tracking, head tracking, body and hand tracking sensors to get rid of serious situations that may occur during a fire [10].

Another area where serious games are used is the defense sector. In this sector, especially the training of military equipment, personnel training, providing information or following changes in behavior and awareness issues can be a subject for serious games [11].

For example, in a study conducted in 2007, it was aimed that the soldiers, who would use them in special missions, to establish correct communication with the people in the region where they will be assigned, and their training in areas such as leadership, cultural transition or questioning was developed [12].

Another example is to determine a method that can be taken during a serious event that may occur in the military field. In the study conducted in 2015, the method by which the city should evacuate in nuclear, biological or chemical attacks that may occur in cities was analyzed [13].

In another study conducted in 2017, different scenarios were applied to training groups and trials were made on casualty evacuation [14].

The platform on which these applications are created are usually game engines. In addition, new technologies are tried to be developed within the game engine. In this context, in an open-source study conducted in 2014, a system was designed to create an object in the area where the user looks in the Unity game engine [15].

In a different study conducted in 2018, the data generated over MATLAB to direct the unmanned aerial vehicles were transferred to Unity, and the virtually created unmanned aerial vehicle was directed within the game engine [16].

As a result of this literature study, it has been revealed that serious games and virtual reality applications have spread to many areas and are used with an increasing frequency in recent years. Especially after such technology and equipment are easily accessible by users, it is seen that the work done in this area has increased and diversified.

The main features that distinguish this study from other studies in the literature are the search for solutions especially for the problem areas encountered in the defense sector, the preparation of the departments for the tasks of the assigned teams, the demonstration of the stages of the application in order, and the explanation of how these programs complement each other by using more than one software together.

III. MATERIAL AND METHODS

A. Measures Against IED

As the name suggests, the IED is handmade and does not have any standardization. They are produced by terrorists within the available possibilities. Similar to mine, IED; They consist of Key System, Current Source, Initiator, Explosive Material, Outer Container. The fact that IEDs are easy to manufacture and supply materials, and their size and shape can be changed according to the

situation, making them more selectable. In addition, they can be transformed into a very effective weapon by terrorists by intervening in the ignition key system as desired.

In this phase of the study in 2010 between the Republic of Turkey in 2019 occurred in the mine and IED threats are evaluated. Almost all of the explosive actions carried out by terrorists between these years were carried out using IED. Between the years mentioned, explosion actions took place mostly on the roads. These areas are followed by the zones within the building or facility and other elements on the roads. In this sense, a significant number of events take place in and around the trench.

B. The Process of Fighting with IED and Capabilities

This study will focus on a certain part of the process of combating IED (Fig. 2). Combat and response process with IED: Material Procurement (about 1 year), Manufacturing (about 2-3 months), Planning (about 1 month), Placement activities (about 1 week), Trigger and Collaborators activities (about 1-2 days) and Detection and Destruction (last few hours or minutes) stages.

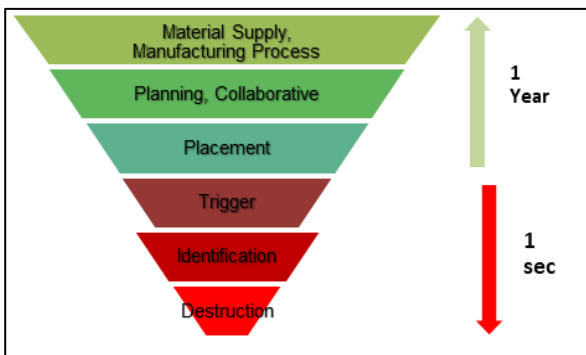


Fig. 2 The Process of Fighting with IED

The most difficult and dangerous part of the fight against IED is the stage of determining IED. Mine detectors are still the most used equipment in the armies of the world to detect these traps, which are very difficult to see and detect. These detectors, which are generally sensitive to metal, are not easy to use, carry, get used to, and move together. These systems, which are not very ergonomic, are sometimes unavoidable to be used by tired, distracted soldiers in combat conditions. Therefore, this study is designed to be beneficial for more detector operators.

C. Preparing a Serious Game Against IED

As shown in a study conducted in 2005 [17], it is possible to create different stages in the preparation of serious games according to the content of the project. In this context, the example steps shown below are carried out sequentially or simultaneously.

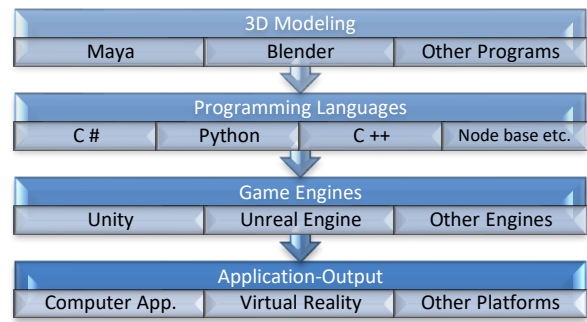


Fig. 3 Example Serious Game Process

D. Modeling of Detector and Operator

Modeling of the character to be used in the serious game can be done with different package modeling programs. However, this modeling requires both a serious skill and technical knowledge. For example, there are many different steps to model and manipulate a human [18]. In this context, different processes are needed in humanoid modeling, such as:

- a. Modeling of solid or organic human model,
- b. Preparation of textures,
- c. Fitting a skeleton system to the model,
- d. Determining the boundaries of the skeletal system,
- e. Determining how much which body particle will be affected for each movement,
- f. Establishment of methods that will enable to act together for muscle group movements.

Although the steps mentioned can be applied sequentially, utilities will be used in this section to ensure the integrity of the study. Many modeling programs can be used for solid body modeling. Blender and Substance Painter were used in this study.

E. Editing Height Maps

One of the most important features that distinguish serious games from other games is that the environmental conditions match the reality. For this purpose, height maps can be used to benefit from real data. Height Maps are black and white colored maps that give a vertical view of the terrain. Each pixel in these maps has a tone between 0-255 and this data is transferred to game engines with modeling programs and turned into terrain (sample height maps [19]). In this study, the height map of the relevant region will be provided from the website called Terrainparty [20]).

F. Game Engines

With this model created, the rules need to be managed through a program. In this context, software called game engine is used. In this way, models and other objects are associated with codes and the application can be prepared.

In today's conditions, many game engines are used. However, two game engines (Unity and Unreal) are used more frequently by users in game development (For detailed content [21] [22]). There are many studies in the

literature on the evaluation of these engines. Considering the increasing number of publications, [23] It was evaluated that it would be appropriate to use Unity game engine in this study.

G. Arrangements in Unity Game Engine

Another important factor is that all interactions to be used in the virtual world are bound by rules. How things like movements, conditions, other environmental elements, and user interface work in the scene can be done relatively simply within Unity. With the drag and drop method, many game objects can be defined in programs. Because the C # programming language is used in Unity, such assignments can be assigned to the code block as game object or variable.

IV. THEORY/CALCULATION

During the application, the modeling of the operator and the land, and some settings in Unity, as well as the basic issues for the creation of tasks and sections will be discussed.

A. Modeling of Detector and Operator

In this study, firstly, a mine detector was modeled with the help of the Blender program, and the parts of this detector were determined as separate objects. Subsequently, UV maps of these parts were created and saved as a Blender file. The Blender file was transferred into Substance Painter program for subsequent use, using standard or smart materials to make the object look realistic and subsequently the object was checked in real light conditions. The activity carried out in this context can be seen in the pictures below.



Fig. 4 Material Assignment to Modeled Detector and Its Appearance under Light

In order to model the operator, the character was modeled in detail with the package program named Adobe Fusion [24], and then the character was transferred to the site named Mixamo [25] to transfer the skeleton system to this model. Mixamo application can create a skeleton system for the model or if desired, different animations can be transferred to the model. In this study, the skeleton system of the model was prepared, and a simple walking animation was added to the model.

To start the animation attached to the created model, an animator has been added to the model in Unity and it has been enabled to work from the beginning of the application without waiting for any conditions (Example Animator adding [26]).

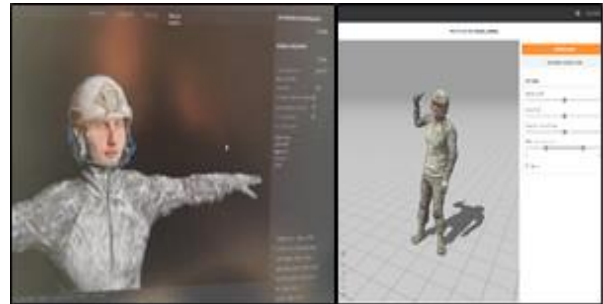


Fig. 5 Character Modeling and Animation

B. Modeling of the Terrain

The internet address Terrain Party was used to obtain the elevation map of the piece of land to be created. After obtaining a height map with an area of 10x10 km belonging to the Tunceli Region (Turkey), the relevant parts of this map were brought to the desired dimensions by editing in photo editing programs and transferred into Unity in PNG format (Fig. 6).

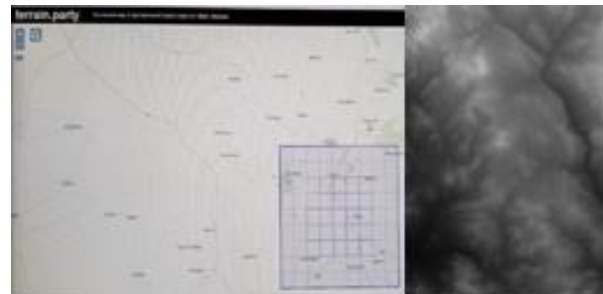


Fig. 6 Editing the Height Map of the Terrain

Subsequently, with an add-on into Unity, the height map obtained in the previous step was selected and the existing standard terrain was converted into the desired 3D terrain (Fig. 7). Simple C # code was used during this conversion process. This modeling process can be done in current Unity versions without the need for any software, via the terrain Editor.



Fig. 7 Terrain Scaling and Material Assignment in Unity

As seen in the study, there is a significant difference in size between the 10 x 10 km land created and the 2 x

2 km land. Considering both the optimization of the model and the time to be spent in modeling such a large land, it was decided to continue the work on a 2 x 2 km land. Subsequently, material assignments to these lands were made based on altitude information with the Terrain-Stratum-Painter plug-in [27] and the terrain was made ready for use.

C. Preparation of Other Elements in Unity

One of the most important factors in the preparation of the land and environmental conditions is the correct adjustment of the light. Placing the light source to create in the game engine at the right angle and intensity will make the application more realistic. In this context, Directional Light was used and tried to obtain daylight values. Similarly, factors such as the movement of the vegetation by the wind and the hearing of environmental sounds are the elements that improve the sense of reality in the application. In this context, standard functions in Unity were used.

D. Transfer of Models and Texture Preparation

Three-dimensional models obtained from various modeling programs or open source need to be transferred to the game engine correctly. Below is a show of how a cover, which has been taken in-game, can be seen during the game by texturing. Originally designed as a simple object (rectangular prism), this cover is textured and transferred into the game using different picture formats.

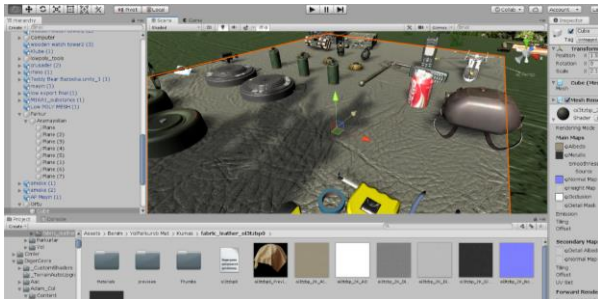


Fig. 8 Sample Texture Representation

The program called Substance Painter was used in the preparation of surface materials, and the free contents in this program's own library were used (Fig. 9). In addition, the following textures were prepared by evaluating the environmental conditions in accordance with the content of the current study.

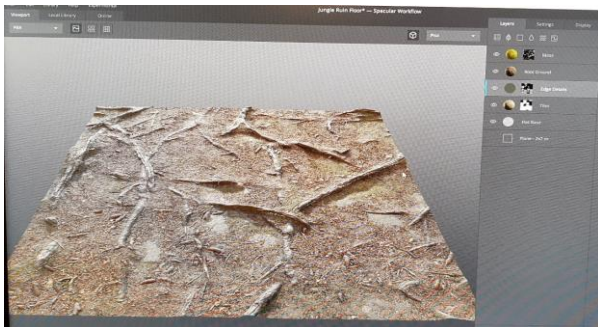


Fig. 9 Preparation of Surface Material

A similar method is used to transfer the mine search detector prepared in the Blender 3D modeling program into the game engine. Not only the model, but also the maps created with the model must be transferred to the object in the game engine in a suitable format.

E. Terrain Design and Preparation of Environmental Conditions

In the previous section, it was stated that elevation maps were used to make the prepared land look like a real piece of land. In order to make this three-dimensional model realistic, it must be covered with suitable material or textured. In this context, the programs mentioned in the previous section and the free content on the official site of the Unity game engine were used (Fig. 10).

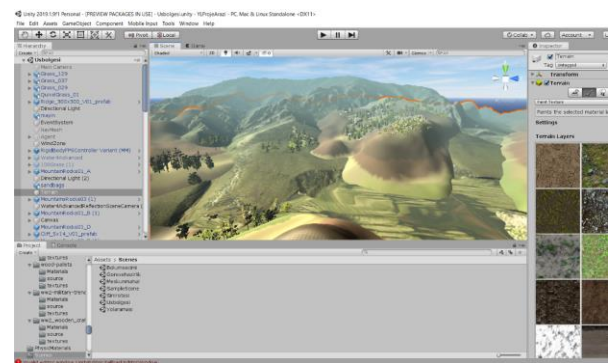


Fig. 10 Preparing the Terrain Model

F. Scenes Design

The serious game, which is planned to be played with keyboard-mouse or other controllers using the computer screen, is designed to consist of five parts. In the determination of the parts (excluding the section selection screen), the tasks frequently performed by the explosives search teams in internal security operations and cross-border operations are based on.

In this context, the first section was prepared to represent the field in which the teams prepare for their duties and at the same time train. The second part is the residential part. In this section, a sample village / neighborhood is designed. The third section is the route search section. This section is based on the search missions of the teams on the road and route. The fourth section is the base area search section. This section focuses on how to search the base areas of the relevant teams before they are occupied. The last section is the cross-border section, and an example of an abandoned, ruined and barren land is modeled in this section.

Scene Of Preparation for Task

This section is the section where teams searching for explosives adjust their equipment and conduct training before going to the field. In this context, the section design consists of two regions. The first zone is the section where the materials are located and displayed.

The second section includes the following search tracks. In these search tracks, detector operators generally search on sandy, stony, pebbly, grassy, and similar areas. As a result of the search and adjustment operations performed in different terrains, the personnel are trained on how the detector signals in different soil types.



Fig. 11 Scene of Preparation for Task

Scene Of Residential Site

In recent years, teams that search for explosives have been searching the most in residential areas. Residential areas provide an advantage to terrorists, especially in hiding explosives. In these areas where each point can be easily hidden, the searchers should check each point in detail, as they consider that this area can be reused by civilians later.

In this context, while designing this section, an example of a residential area with buildings placed on the right and left on a road and a street in the middle was modeled, and various obstacles and objects that could be encountered frequently were placed in it. In this way, it is aimed for the detector operator to evaluate each object as a dangerous and approach accordingly.



Fig. 12 Scene of Residential Site

Scene Of Searching for the Base Area

Another task frequently encountered by explosive-seeking teams during internal security operations and cross-border operations is the base area search missions. Base areas are generally opened and closed according to need and time. The troops spread over the land usually go to their missions from these points or end their duties

at these points. When base regions are used for the first time, they should be searched in detail. These missions require a special sensitivity due to the fact that a long time has passed, and these regions are known by terrorists.

In addition, since it is considered that previously used positions or frequently used points can be trapped by terrorist elements, these points should be searched with extreme precision. In this context, a base area was modeled in accordance with the land in the Tunceli region and it was aimed to search this area by detector operators duly.

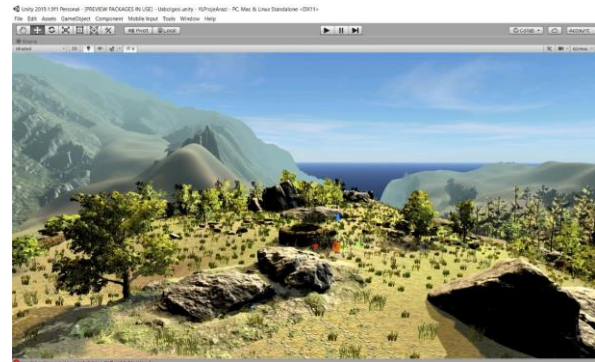


Fig. 13 Scene of Searching for the Base Area

Scene of Road Search

A pedestrian or vehicle deployment is made at the beginning or end of almost all missions. In all of the transfers carried out, it is necessary to search for an explosive substance on the route where the movement will be carried out. For this reason, explosive substance search teams have to search for all kinds of roads, their surroundings and when necessary, critical points. In this context, a section has been designed to train the elements that will make a road search in the field.

It should be taken into consideration that areas with different soil structure will be searched in road and route searches. While the surface of the road may be asphalt, the edge of the road may be soil, and a little further it can be bush. Even under the roads, tunnels, cables and culverts often pass. Since these areas are considered to be easily trapped, these points should be searched in detail.



Fig. 14 Scene of Road Search

(Scene Of Cross Border

As a result of the changing and developing conjuncture, cross-border operations were added to the duties of the teams searching for explosives. Especially in sandy, barren and desert-shaped lands, it is necessary to search the ruined, abandoned places or buildings and interiors. Although these areas are not common in every country's geography, it has been evaluated that it would be appropriate to add to this application when the tasks performed in recent years are evaluated.

For this reason, it was aimed to model this section in a realistic way and a ready-made and free section in the Unity Store was optimized and used. The aim is to search among and within the collapsed buildings and desert land within the scene.



Fig. 15 Scene of Cross Border

G. Preparing the User Interface

Below is the C # code showing how to switch between sections. Selecting the sections, changing the color of the selection when the mouse cursor is over it, changing the color of the relevant tab as a result of the signal, or the visual settings of all tabs have been prepared using the Text Mesh Pro plugin in the Unity game engine.



Fig. 16 User Interface

There are 3 panels that interact with different users on the screen where the game application is used. The first of these is the radar panel at the top right of the screen. Through this panel, the user can see himself in the field as a bird's eye view and estimate his location. The second is the area in the lower right corner where the detector is placed to represent the signal sensor. In this area, the user notices the signals coming to the detector visually. Finally, it is the area at the bottom left where the calculations regarding the distance take place. Here, a numerical value is obtained by measuring the

distance between the center point of the detector and the center points of the explosive substance.

C # Code Using Distance Measuring and Other Fields

```
public class Distance_Measuring: MonoBehaviour
{
    public GameObject metal;
    public GameObject searchhead;
    float distance;
    public Text distancetext;
    public Text valuetext;
    public Slider indicator;
    public AudioSource signal;

    void Start()
    {
        signal = GetComponent<AudioSource>();
    }
    void Update()
    {
        distance = Vector3.Distance(metal.transform.position,
        searchhead.transform.position);

        if (distance < 0.3f)
        { distancetext.color = Color.red;
        sinyal.Play();
        }
        else
        distancetext.color = Color.white;

        sinyal.volume = 1 / (1 + (distance * distance));
        indicator.value = (1 / (distance * distance));
        distancetext.text = ("Mesafe = " + ((1 / (1 + (distance *
        distance))))).ToString();
        valuetext.text = "Değer= " + distance.ToString();
    }
}
```

H. Placing Explosives and Signs in the Terrain

An important factor affecting the realism in the creation of the content of the scenes is the detection of explosive substances placed on the land and various signs at different points each time. Thus, when the player restarts the episode, he will have to detect the explosive substances and signs he has encountered before at different points. In this context, a C # code has been written to ensure that explosives are generated in a random area at the start of each game.

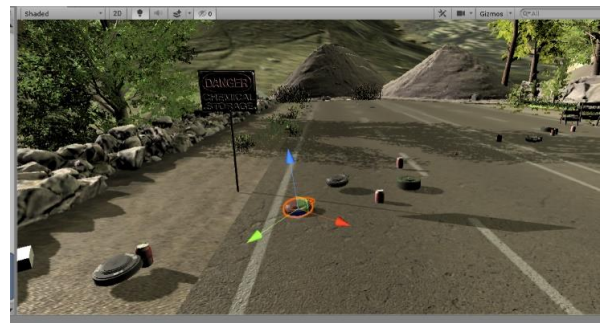


Fig. 17 Random Creation of Explosives

C # Code that allows explosive substances to occur randomly

```
void Start()
{for(int i=0; i<= number_of_explosives; i++)
    GenerateExplosive();
}
public void GenerateExplosive()
```



```

{ Vector3 position = new Vector3(
    Random.Range(startpoint.x, endpoint.x),
    Random.Range(startpoint.y, endpoint.y),
    Random.Range(startpoint.z, endpoint.z));
  Instantiate(explosive, position, explosive.transform.rotation);
}

```

I. Scene Manager and Build

The stage manager is a template that is prepared to return to the main menu from the section you are in the main menu or any section during the game or to switch to the section you want in the main menu and this template is supported by C # code.

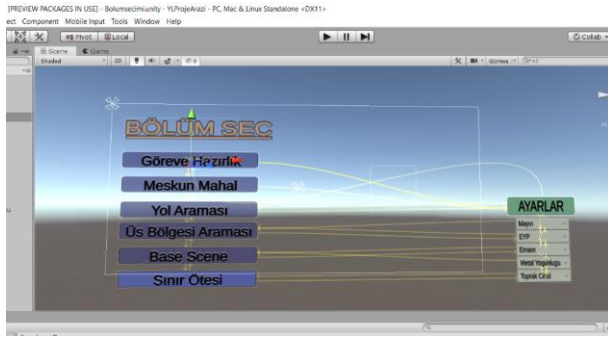


Fig. 18 Preparing the Scene Manager

The Unity interface makes this kind of programming very easy. Below is a sample scene manager code.

Scene Selection C # code:

```

public class Bolumsecimi : MonoBehaviour
{
    public void Gorevehazirlık() {
        SceneManager.LoadScene(1);
    }

    public void Meskunmahal() {
        SceneManager.LoadScene(2);
    }

    public void Yolaramasi() {
        SceneManager.LoadScene(4);
    }

    public void Usbolgesiaramasi() {
        SceneManager.LoadScene(3);
    }

    public void Basescene() {
        SceneManager.LoadScene(5);
    }

    public void Sinirotesi() {
        SceneManager.LoadScene(6);
    }
}

```

The panel where all these prepared scenes are combined and converted into an application is the Build Setting panel. The game parts prepared through this panel are made into one piece and the output is created on whichever platform the application is prepared.

J. Result and Discussion of the Application

In this study, first of all, the needs of teams searching for explosives were evaluated and a serious game application was made. The scenarios that the relevant teams may encounter in this application are considered and scenes are designed accordingly. In this context, environmental elements, terrain, explosives and mine search detectors were modeled and transferred into the game engine. The serious game has been made ready with the arrangements made in the game engine.

V. CONCLUSIONS

In this study, first, the needs of teams searching for explosives were evaluated and a serious game application was made. The scenarios that the relevant teams may encounter in this application are considered and scenes are designed accordingly. In this context, environmental elements, terrain, explosives, and mine search detectors were modeled and transferred into the game engine. The serious game has been made ready with the arrangements made in the game engine.

With this study, sample virtual missions were created according to the scenarios that the teams performing the task of detecting and destroying explosives in the Unity game engine. In this way, teams will be able to improve their skills by training before going on these missions, and at the same time, they will be able to gain experience in detecting, diagnosing, and destroying situations, scenarios or explosives they have never encountered before.

Considering that a one-percent error would be considered a failure for teams intervening in explosives, it will be understood how important the use of this, and similar studies is. It is considered that the continuation of these and similar studies will positively contribute to the training of personnel working in difficult conditions and the personnel working in the defense sector. Considering the cost of training these personnel, similar applications are cost effective solutions.

In future studies, it is considered that it will be beneficial to try technologies that motivate the user, especially by using virtual, augmented, and mixed reality glasses. In addition, it considers that many dangerous issues in the defense sector (for example, deployment, ambush and resisting ambush, weapon simulators, combat in residential areas, etc.) may be subject to further studies.

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