Training of Drone Pilots through Virtual Reality Environments under the Gamification Approach in a University Context.

Héctor Cardona-Reyes[1], Cristian Trujillo-Espinoza[2], Carlos Arevalo-Mercado[3], Jaime Muñoz-Arteaga[3],

[1] CONACYT Research fellow, CIMAT Zacatecas, Mexico
hector.cardona@cimat.mx
[2] Center for Research in Mathematics, Quantum: Knowledge City, Zacatecas, Mexico
cristian.trujillo@cimat.mx
[3] Autonomous University of Aguascalientes, Aguascalientes, México
{carlos.arevalo,jaime.munoz}@edu.uaa.mx

Abstract. Drones have been characterized by their diverse applications in the fields of industry. Nowadays, their use in the context of education is becoming more and more frequent and their popularity has increased due to their affordable cost, variety according to the needs of each user. This implies that users with different capabilities, social and educational contexts need to acquire the necessary skills to pilot drones safely, considering the type of task to be performed and the specific drone. Taking into account these aspects, a gamification approach allows young people to work on their skills to solve real problems under a game mechanic in order to obtain better results. In urban environments, training with a real drone involves physical risks. Therefore, learning to fly drones through virtual reality environments can bring additional advantages, since it is not necessary to have a physical device and can be a fun alternative for learning and acquiring skills. For the creation of these virtual environments, it is important the collaborative work of various stakeholders, from software designers, experts in the handling of drones, and educators in order to provide environments focused on the needs of the user. This work presents design elements under a proposed model for the production of virtual reality environments focused on teaching drone piloting in simulated and real scenarios. The results obtained with the test cases of the proposed environments in a sample of higher education students are presented and the user experience is analyzed for further improvement.

Keywords: virtual reality, interactive environments, drone, education.

1 Introduction

The term Unnamed Aerial Vehicles (UAVs) encompasses those unmanned aviation systems. The popular term for such systems is known as “drones”, as people associate them with aircraft without a pilot on board and operated by remote control or computer. Drones have been used in a variety of applications, for example, military drones used in missions during the Vietnam War [1]. Other applications of drone use include monitoring and preservation of species in forests, agricultural applications, and promising advances in the field of commercial logistics and product delivery [2], as shown in the example in Figure 1.

Fig. 1. Example of commercial drone used by Amazon to deliver packages in less than 30 minutes [3].

The use of drones has brought with it several advantages, which include being able to perform tasks in high-risk or difficult-to-access areas. Pilots can operate from a safe area at all times. Many sectors have been favored as the range of applications expands by incorporating artificial intelligence and Virtual Reality (VR) [4]. Such is the case of mapping applications, people monitoring, object recognition, and police operations, among others.

Given this scenario, there are several efforts to have standards to regulate the proper use of these devices. To mention some examples, in Mexico, the Mexican Official Standard (NORMA Oficial Mexicana NOM-107-SCT3-2019) [5] establishes the requirements to operate a remotely piloted aircraft system in Mexican airspace. In Spain there is the State Agency for Air Safety (AESA) [6], which has as its purpose the missions of Supervision, Inspection and Management of Air Transport, Air Navigation and Airport Security, it also evaluates the risks in transport safety and has the power to sanction violations of civil aviation regulations and in the United States, there is the Federal Aviation Administration (FAA) [7], which is responsible for aviation safety and regulations. It operates the airspace traffic control.

Nowadays, factors such as the development of technology, cost reduction, and the need to simplify tasks efficiently and safely have made it possible for drones to be more widely accepted and used by a wide variety of users [8]. Thus, the need arises for strategies to train users to be able to drone according to the context of use. In this sense, the growing number of drone pilots and applications, together with the great variety in the market, has led to the establishment of schools where users can be trained in drone pilot training and education.

According to the Spanish State Agency for Aviation Safety (Agencia Estatal de Seguridad Aérea AESA), there are 74 schools dedicated to drone pilot training. The objective is to provide the best strategies to train pilots favoring the reduction of costs and risks in a safe simulation environment [8], [9].

Simulation has been a key element in various forms of training, from automobiles, submarines, airplanes, etc. These proposals usually use strategies based on gamification for the user to play and move forward in obtaining their goals. Nowadays we can find this type of applications available on video game consoles to professional simulators used by companies, although the trend also points to mobile devices and virtual reality systems for home use [10], [11]. In the case of UAVs, simulation allows to representation of scenarios close to reality, devices with specific characteristics, and environmental conditions that can hardly be found in reality. This brings with it a cost reduction by avoiding accidents, equipment damage, among others [12].

This work presents design elements under a proposed model for the production of virtual reality environments as an option to train users in the use of drones under a gamification approach that allows the user to perform the tasks established in the existing official standards to train drones pilots safely and playfully. Therefore, the production of these virtual environments under the proposed model requires considering some of the following challenges:

- Identify the design elements for the creation of virtual environments.
- Identify the actors involved such as technologists, drone experts, designers, etc. Which collaborate for the proposal and creation of virtual environments according to the user's needs.
- Define the gamification elements according to the proposed scenarios within the virtual environments.
- Identify the context of the use of drone simulation within virtual environments.
- Identify the user interface to the user tasks within the virtual environment.
- Define the appropriate technology for the proposed task according to the type of user.

In this work, a proposal for a virtual reality environment focused on teenagers and children is presented so that they can be trained in the recreational use of drones through a simulation in a VR version and augmented reality environment.

This work is composed of seven sections, the next section presents a series of works where the use of virtual reality environments and applications in drones ranging from applications in industry, research, and education is presented. Section three introduces the topic of drones, their classifications, the existing guidelines, and the types of users that exist to pilot drones. Section four proposes a model for the production of these interactive environments. Section five presents a case study where a virtual reality environment is implemented to train recreational pilots and section six presents the results obtained. Finally, the conclusions and future work are presented in section seven.

2 Related Work

In the literature, several works can be found that propose simulation strategies and their applications for the training of users for the operation of various UAVs. It is also important to explore those works that address the ways of evaluating the user experience in order to have an overview of the existing techniques for evaluating the user's perception of this type of interactive systems. These works propose developments based on virtual reality using complex navigation and route tracking systems, others include the design of complex mathematical models to simulate specific conditions for UAVs. The use of drones in the educational context and the benefits related to their use by teachers within their school courses are also proposed. Some of this work is described below.

- Nguyen [13] proposed a web-based route planning and navigation system called DroneVR, it is a virtual reality system that uses OpenStreetMaps [14] as a basis to have real-world flight data and uses mathematical models to predict object movements and plan tracking strategies.
- Khuwaja [15] presents a flight simulator for Quadropter UAVs for training drone pilots before a real flight. The system is based on virtual reality and allows measuring the pilot's performance under the simulated environment. The pilot can always receive visual feedback on the simulated model he is executing.
- Liu [16] presents a virtual reality system in which he proposes a technique to simulate UAVs using the Unreal Engine video game engine. This proposal allows students to enter effectively and safely under various environmental conditions within the simulated environment.
- The recent use of drones in the educational context has been an effective solution by educators to mitigate low attendance problems, improve discipline and increase student satisfaction [17]. The constant search for strategies to support STEAM (science, technology, engineering, arts, and math's) [18] has allowed the incorporation of drones as a means to improve knowledge retention and the development of basic skills such as fine and gross motor skills when piloting this type of UAVs. In addition to the benefits of incorporating the use of drones in school activities, we can find the motivational factor and provide a fun learning environment [19].
- Kretschmer et al. [20] present a proposal for a serious game for the interlogistic sector, in this proposal a VR-based game was analyzed in which usability, user experience, workload, and motivational aspects were considered as evaluation aspects. In their results obtained they present that virtual training is characterized by good usability, user experience, and moderate mental workload. They conclude that the use of virtual training is a promising and effective alternative to traditional methods.
- Yam-Viramontes et al. [21] present the use of Natural User Interfaces (NUI) using body gestures to control a drone. This proposal was implemented through a real type of experiment with different users and an evaluation of the user experience was carried out through a User Experience Questionnaire (UEQ), showing good results in terms of usability and user experience.

- Somrak et al. [22] presented a review, compared, and evaluated the adequacy of existing standard measures for assessing Virtual Reality-Induced Symptoms and Effects (VRISE) and user experience in VR. For this they have experimented with a VR game and evaluated the user experience, using the User Experience Questionnaire (UEQ-S) and the Virtual Reality Neuroscience Questionnaire (VRNQ) to assess aspects of VRISE and user experience. In this study, they prove that the instruments used for the evaluation of user experience have been effective and of great utility for this type of VR environments.

The use of drones increasingly encompasses many application fields that include their use in risk and reconnaissance missions to being an influential factor in the development of skills within a school context. Hence the importance of proposing solutions that can help users to be trained in their handling.

3 Drones and Users

A drone in technical terms is a flying robot that is controlled remotely and usually integrates a set of sensors such as GPS and cameras with specific characteristics that allow it to be used for a specific purpose [23].

Drones are divided into two main groups, those that are considered autonomous because they do not require human intervention during their operation. And those with remote control, which are those that require a pilot acting permanently in the operation [8]. Several authors [24], [25] present a categorization of drones according to their designation characteristics such as their flight range and weight.

The characteristics of each drone serve a specific application, thus the type of user required so that they can be piloted. In this sense, a user classification is presented, which is generalized into three main types [7], [26]:

- Recreational users are generally those who are new to drones and their application refers to photography and video, tourist use, and recreational and leisure applications. In general, the drones used are accessible and low-cost and can even be used by teenagers and children for domestic use.
- Professional users are those who have experience in handling drones and their use is more complex and refers to commercial applications, such as police monitoring, mapping applications, agriculture, among others. These types of users must know the technical and regulatory aspects of drones. They must be familiar with airspace and radio spectrum regulations, safety, and environmental aspects.
- Training entities are those who belong to organizations and technical schools or universities and who are certified to train personnel in drone operation. They usually offer certifications, workshops, and courses for professional users and companies that need to train their personnel.

Piloting a drone is as important as piloting any other vehicle; existing regulations, safety guidelines, and restrictions must be taken into account [26]. Therefore, it is necessary to acquire prior learning that allows knowing the key elements according to the needs of each user.

4 Production of virtual environments for the training of drone pilots.

This section presents design elements under a proposed model for the production of virtual reality environments for drone pilot training. These virtual reality environments produced will be oriented to the different types of users identified in Section 3. For the production of these virtual reality environments, it is necessary to form a multidisciplinary team that combines regulatory, safety, technical, and technological aspects that allow the proper representation of the various types of drones and scenarios in an immersive environment. Additionally, virtual reality environments are sought to have aspects of gamification [27] by incorporating elements that awaken the user's interest with dynamics such as rewards, competition, achievement, among others, in a playful context in which the motivation of users can be increased to achieve the training objectives and offer a rewarding experience. The elements of the proposed model in Figure 2 are described below.

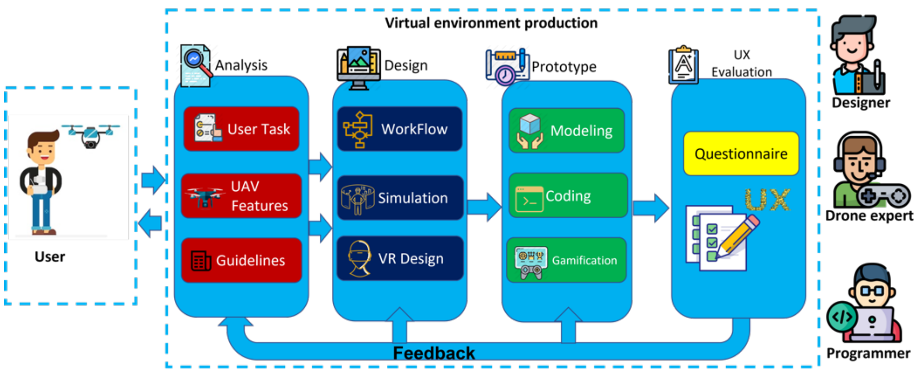


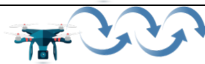
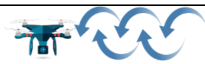
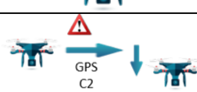
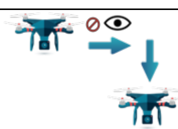
Fig. 2. Model for the production of virtual reality environments for drone pilot training, inspired by Saltiveri [28].

4.1 Analysis

In this stage, the necessary elements are identified so that the virtual reality environment complies with the characteristics according to the type of user to which it will be oriented. In this sense, the user tasks to be performed within the simulation environment are identified, the drone characteristics for its correct representation in virtual reality, and the guidelines according to the training standards are identified. The training tasks include those activities defined by the regulatory institutions related to aviation safety. These activities are practices that aspiring pilots must pass in order to obtain a certification. The objective of the practices is to help the aspirants to achieve the necessary expertise in drone handling and thus meet the requirements of certification. Table 1 presents an example of the exercises applied by the State Agency for Aviation Safety (AESA) of the Government of Spain so that an aspiring pilot can be certified [6].

As part of pilot training, virtual reality environments are intended to support pilot training based on existing standards and guidelines so that all the skills that a pilot must acquire can be adequately covered. Once the training context, the type of drone, the training activities to be performed and the proposed tasks to be carried out within the simulation environment have been identified, we proceed to the design stage of the virtual reality environment and the construction of the prototype.

Table 1. Drone pilot training exercises, source AESA Spain [6].

Exercise	Image
Exercise 1: Take off the multicopter 10 meters away from you, raise it to eye level, and hover for 10 seconds.	
Exercise 2: Steer the drone forward in slow flight and 20 meters high. During its trajectory, make it zigzag (S-shaped trajectory) by making a minimum of 4-course changes.	
Exercise 3: Same as exercise 2 but making the drone fly backward (towards you / the pilot). Try to make the aircraft face towards you, so that the controls are reversed if the drone does not have the headless mode.	
Exercise 4: Steer the multicopter laterally, both left and right, making it reach a distance of up to 30 meters on each side of the pilot.	
Exercise 5: Ascend the drone to a minimum height of 50 meters. Then, make the multicopter descend in a spiral making a 360° turn to the right, and another 360° turn to the left with the orientation of the multirotor always in the direction of its path. The drone must end up in front of the pilot.	
Exercise 6: Take off the drone and direct it to make a rectangular circuit with two turns (turns) of 90° to the right. The multirotor must always be oriented in the direction of the trajectory, and it must land facing the pilot.	
Exercise 7: Take off the drone and steer it to perform a rectangular circuit, landing the drone 50 meters away from the pilot. In this exercise, the drone does NOT have to be always oriented in the direction of its trajectory.	
Exercise 8: With the drone at a minimum height of 50 meters above the ground, try to lose sight of it and regain it to land it by re-establishing eye contact.	
Exercise 9: Use the aircraft's intelligent flight modes, if any, especially the «Return to Home» mode (RTH).	

4.2 Design and Prototype

In this stage, the design elements for the production of virtual reality environments are defined, together with the components and tools necessary for the generation of prototypes that can be implemented with the users in the training sessions. The design stage is mainly composed of three elements.

- Workflow: Refers to all the activities that the user will perform within the virtual reality scenario, ranging from the instructions to interact with the scenario and the objectives to be covered when executing the training tasks.
- Simulation: Based on the tasks defined by the user and the drone guidelines, the characteristics of the simulation to be recreated are determined.
- Virtual Reality Design: Virtual reality elements are included, such as the drone model with physical characteristics according to the identified UAV guidelines, the objects with which the user will interact and the objects that will be static within the scenario are also considered.

For the construction of the prototype, it is necessary to take into account the modeling tools available for the representation of 3D objects in the simulated environment. Video game engines such as Unity3D [29] and Unreal Engine [30] are used to give physical properties and behavior to the objects in the virtual environment. The representation of the user interface is an aspect of great importance since this interface should be as similar as possible to the basic control of the drone that is intended to be incorporated into the virtual reality environment.

It is necessary to identify the basic control to operate a drone and to know the essential handling functions. Identifying these functions will allow to design as close as possible the drone operation interface within the virtual reality environment and to familiarize the user during the simulation and training exercises so that when he/she is in front of a real drone, he/she will be able to operate it properly. Below are some of the basic functions that make up the basic control of a drone presented in Figure 3 [31].

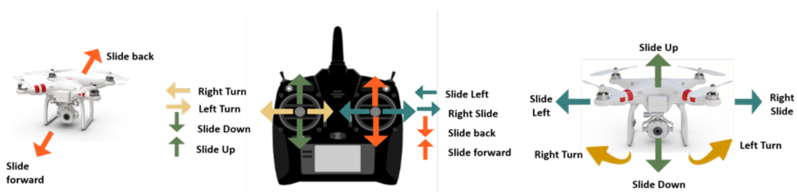


Fig. 3. Basic drone operation control [31].

- Speed button: allows you to change the speed of the drone in flight. This function is widely used by new users who start flying drones.
- Throttle: allows you to raise and lower the drone while in flight.
- On/Off: allows you to turn the drone on and off and turn off the controller.
- Looping: allows the drone to perform 360 degree turns in the air.

- Movement lever: allows you to move the drone forward and backward (forward and reverse), as well as left and right.
- Fine adjustment button: allows the drone to move forward and backward in a precise manner.

For the construction of the prototype, it is important to consider the architectural design of the system. This is divided into two important parts, the user tasks, and the virtual reality environment, as presented in Figure 4.

The user task component involves two activities, the first is that the user must acquire theoretical knowledge about the operation of the drone and the second part refers to the practical exercises to be performed within the virtual environment. The system always provides real-time feedback through the input and output devices such as the controls, the interface, and the virtual reality headset.

The virtual reality component is the one that contains the 3D models that represent real-world objects, such as the drone, training scenarios, and dynamic objects within the scene. Another important aspect is the incorporation of gamification strategies that will keep the user's interest and increase motivation when using the virtual reality environment. Some of the gamification aspects that can be incorporated are [27], [32]:

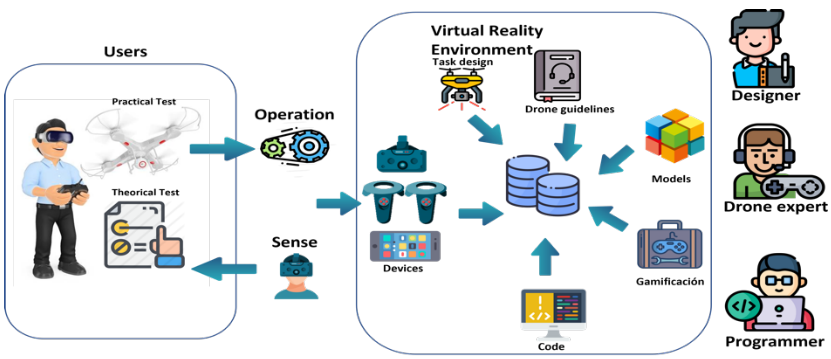


Fig. 4. Proposed architecture for the production of virtual reality environments, based on Zhang [33] and Burdea [4].

- Accumulation of points: a qualitative value is assigned to certain actions, and they are accumulated as they are performed.
- Level escalation: a series of levels that the user must overcome to reach the next one is defined.
- Obtaining prizes: as different objectives are achieved; prizes are awarded to be collected.
- Gifts: These are goods that are given to the player for free when an objective is achieved.
- Classifications: users are categorized according to the objectives achieved, highlighting the best ones in a list, or ranking.
- Challenges: it encourages competition among users, the best one gets the points or the prize.

- Missions or challenges: solve or overcome a challenge or objective.

Finally, the architecture of the system considers, in addition to the users, a designer for the generation of 3D models and a programmer for the coding using Frameworks and virtual reality engines for the production of the virtual reality environment in a variety of platforms available to the user.

4.3 Evaluation

User evaluation is a fundamental part of obtaining feedback and providing improvements to virtual reality environments. Feedback can be represented in two ways. The first is through indicators that are presented to the user and that are linked to gamification strategies. For example, by achieving a certain number of points, or completing a certain number of tasks, unlocking levels, etc. The second part of the feedback is that which is obtained to analyze the user's performance, this can be stored in the form of a data structure to know the time it takes the user to perform certain tasks, record the movements made, among others. This information helps instructors to perform an analysis and to know the user's progress in terms of training and performance.

It is also important to consider the evaluation of the user experience, these evaluations allow to know the perception of use and usefulness of the system, as well as aspects such as ease of use, and how the user generally perceives to use it in their training activities. The results of these evaluations will allow improving the virtual reality environments to increase the acceptance by users and trainers.

In the literature, we can find several instruments that can help to evaluate the user experience. The User Experience Questionnaire (UEQ) [34], allows knowing the user's impression about the virtual reality scenario (Attractiveness), if it is to his liking, if he feels familiar and if it is easy to learn how to use the software (Perspicuity). The Computer System Usability Questionnaire (CSUQ) [35], is very useful when it is desired to know if the system is easy to use. Other questionnaires such as the AttrakDiff [36], [37] allow us to know and evaluate aspects related to the functionality and usability of the proposed scenarios, as well as aspects related to people's skills and attitudes regarding how users interact with the virtual scenarios.

The following section presents as a case study the design and implementation of the virtual reality environment "Training Drone" for the training of recreational drone pilots.

5 Virtual Reality Environment for Recreational Users Training-Drone.

Next, the design elements and the implementation of the virtual reality environment oriented to recreational users "Training Drone" under the proposed model of Section 4 are presented. This case study was carried out at the Autonomous University of

Aguascalientes with 30 students between the ages of 20 and 25 years from the careers of systems engineering and information technology.

It was led by 2 professors in charge of teaching courses to the aforementioned careers, among activities that were carried out, students were invited to participate in the study, follow up with the questionnaires applied and after completing the test to perform the analysis of results with the information obtained from the application, in addition, it was carried out, the preparation of the application to be accessible to students and could be installed on their mobile devices.

Regarding the application, for its development, we had the collaboration of a drone expert for the design of the scenarios and exercises to be performed and as support in the existing regulations for recreational users [6], [7], also a designer for the creation of the virtual scenarios and the selection of the drone to simulate, and a programmer for the coding of the virtual elements, the registration of information in real-time in the database, the coding of both VR version and augmented reality scenarios.

This application was developed on the Unity3D platform and has access to a real-time database through the Firebase platform to capture user performance information and was compiled for Android devices.

For this application, 2 types of scenarios were considered within the same application, a VR version, and an Augmented Reality (AR) [38] version. The purpose of integrating an AR version of the scenario was to know the user's perception of each of the versions and thus obtain feedback for future improvements. Another reason was to be able to adapt the design elements of the virtual environment of the proposal to a different form of representation such as augmented reality, this gave us the guideline to reuse design elements for the production of new virtual environments.

The main motivation of this case study was the implementation of a virtual environment under the proposed model with a recreational user profile, in addition to identifying the perception of the user interface, the controls to handle the virtual drone, the proposed exercises, the integrated gamification elements, and the overall user experience. Each of the stages of this case study is presented below.

5.1 Analysis

Training Drone consists of two versions, one version where the scenario contains 3D elements and represents a training area for flying drones. The second version uses augmented reality so that the user can indicate the physical area and provide a sense of realism by combining real-world elements with virtual elements.

When users start the application, they must enter their basic information, such as name and age, to track their performance which will be stored in a Firebase database in real-time [39]. After entering the information, one of the two available versions can be selected. A VR version resembles a test area as it contains animated elements, and the scenario simulates a flight and training area. On the other hand, the augmented reality version adapts to the physical space indicated by the user.

After selecting a version, a set of instructions for use are presented in the form of audio, at the end of the instructions an option is enabled on the screen to start the activities and the basic operation controls of the drone are shown, these controls follow the operation guidelines described in Section 4.2. At that moment, audio prompts the user the instructions related to exercise 1, after being completed the instructions to perform exercise 2 are given, until completing the 4 exercises established for a recreational user. These exercises are based on the guidelines described in Section 4.1.

It is worth mentioning that in each exercise the user must collect a series of coins that also help to be a guide to perform the indicated movements. During this process, information is sent to the database where the duration in time of each activity, the number of coins collected, and the movements made by the user to complete the exercises are stored.

Figure 5 shows a classification of exercises and types of drones proposed for the different types of users, with it is intended that the virtual reality environments produced to contain the appropriate exercises for each type of user.

User	Training Type	Activities	Usable drones
Recreational User	BEGINNER	Exercise 1, Exercise 2 Exercise 3, Exercise 4, Exercise 9	Conventional, Coaxial, Nano, Tricopter, Quadcopter, Hexacopter, Hexacopter
Professional User	INTERMEDIATE, ADVANCED	Exercise 1, Exercise 2 Exercise 3, Exercise 4, Exercise 5, Exercise 6, Exercise 7, Exercise 9	Tricopter, Quadcopter, Hexacopter, MALE´,HALE´
Training Entities	ADVANCED, EXPERT	Exercise 1, Exercise 2, Exercise 3, Exercise 4, Exercise 5 , Exercise 6, Exercise 7, Exercise 8, Exercise 9	Tricopter, Quadcopter, Hexacopter, MALE´, HALE´, Hybrids

Fig. 5. Classification training exercises according to the type of user, based on Zhang [33] and Burdea [4].

5.2 Design and Prototype

As part of the workflow design, the modeling of tasks to be performed by users within the virtual environment was established. This modeling is mainly aimed at obtaining more user-centered interactive applications. The advantage offered by this modeling is to have a hierarchical structure of abstraction levels when analyzing the tasks within the context of drone management. In addition, it is easy to understand for both users and designers and thus fosters collaboration between experts in the drone context, software designers, and the user context. Figure 6 presents the design under the Concur Task Trees (CTT) notation [40] of exercises 1 and 2 described in Table 1 and Figure 5 for recreational users.

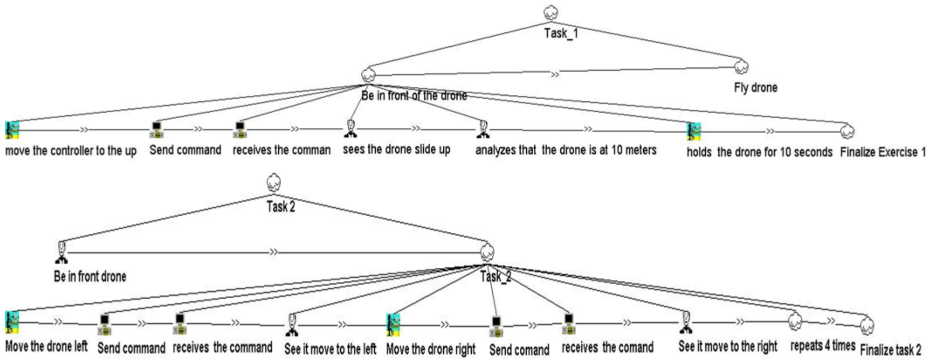


Fig. 6. Modeling of tasks of exercises 1 and 2 for recreational users under the CTT notation [40].

Regarding the design of the system, the class design of the Training Drone virtual reality environment (see Figure 7) is composed of a UserManager class that manages the information that will be stored in real-time and sent to the DatabaseConnection entity type class which in turn connects to the external Firebase service. The class LevelManager also controls the sequence of tasks to be performed by the user. The class Task oversees controlling the information defined from each task and sends it to DatabaseConnection for its storage after completion. UserManager oversees registering user information and displaying operation instructions to the user. This class, together with the MainUI and DroneControl classes, oversees the drone control interface.

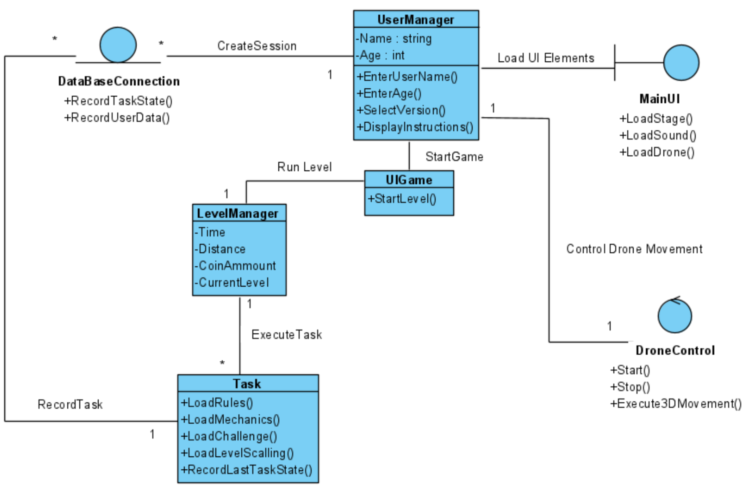


Fig. 7. Class diagram of the virtual reality environment Training Drone.

For the development of Training Drone, the Unity3D videogame engine was used because it allows the creation of 3D scenarios, coding the behavior of objects in the scene and assigning them a specific behavior. Also, it allows the reuse of 3D models and has a wide range of resources available for free. For the development of the VR version, a set of Assets was used to build the scenery and the drone used. The augmented reality version was developed under the ARCore framework [41] that allows the integration of augmented reality elements and is compatible with mobile platforms such as Android and IOS. Both versions of Training Drone use a drone with four rotors and four propellers, this type of drone being more common for recreational users. As shown in Figure 8.

Fig. 8. Training Drone virtual reality environment. a) VR version, b) Augmented reality version.

5.3 Evaluation

The procedure started with providing the students with the APK (Android Application Package) file [42] to be installed on their Android mobile devices. They were then asked to launch the application, enter their information, and perform the four exercises presented.

The procedure performed was simple. The APK file was provided to be installed on their Android mobile device and the user was asked to follow the system prompts until completing the four drone pilot training exercises. These exercises are designed under the practices that are performed to train drone pilots for recreational users. The design of the exercises can be seen in Figure 9. The instructions for each of the exercises within Training Drone are described below.

- Exercise 1: Take off the multicopter up to the height of your eyes, raise it to the green arrow and keep it in stationary flight for 10 seconds. Try to touch the coins on your way.
- Exercise 2: Steer the drone forward in slow flight, during its trajectory pick up the coins in a zigzag motion (S-shaped trajectory), make a minimum of 4-course changes.
- Exercise 3: Same as exercise 2. Turn the drone towards you. Try to keep the aircraft oriented towards you.

- Exercise 4: Steer the multicopter sideways, both left and right. Take as reference the coins located on each side.

As part of the evaluation of the user experience and to know the perception of the system. After the student performed the exercises, he was asked to answer a survey which captures aspects of perception of the use of this type of virtual reality environments, the preference between the two proposed versions VR and AR, if he considers the proposed exercises complicated and a section of questions based on the User Experience Questionnaire UEQ [34]. The following section presents the results obtained from the implementation of the Virtual environment Training Drone.

Fig. 9. Training Drone virtual environment exercises for recreational users. 1) Take-off and elevation of the multicopter. 2) Movements in trajectory S. 3) Oriental the ship to the user. 4) Lateral movements left/right. 5) AR version of Training Drone virtual environment.

6 Results

This section presents the results obtained from the case study presented in section 5.3. In this case study, 2 questionnaires were applied, the first one consists of a general survey created in Google Forms which was answered by the students after using the application and in order to know general user information, their experience in drone handling, their general perception of the drone control interface, and the perception about the 2 versions of the virtual environment either the VR or AR version. A second questionnaire was applied via Google Forms to learn about the user experience and perception of system usage, this survey is based on the UEQ questionnaire [43].

Regarding the results of the first questionnaire, it was found that approximately 86% of the students have no experience in handling drones, only 13% said to have flown one at some time. It was also observed that, of the two versions proposed, the

VR version had a 72% preference among students, against 13% for the augmented reality version.

The students' argument for the preference of the VR version is that the training scenario is visually more attractive because of the 3D objects present, the design of the scenario that resembles a training field. As for the augmented reality version students expressed the feeling of difficulty in combining the real scenario with virtual objects, they expressed a feeling that the drone at some point was going to get lost or get out of control of the camera.

Regarding the basic control interface of the drone, most of the students expressed as an additional comment in the survey, that they are difficult to use at the beginning because of the sensitivity with which the drone moves, but as time goes by and they perform the exercises they acquire the ability to control the drone.

In addition to these two questionnaires, the information obtained from the application database was analyzed to know the performance of the users when using the mobile application and performing each of the exercises presented. This analysis mainly takes the time it took to perform each of the 4 proposed exercises.

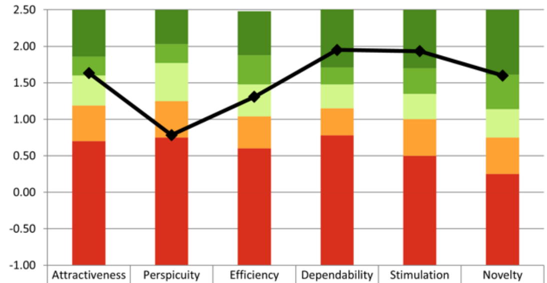
Although the students expressed difficulty when working with the augmented reality version, the times obtained are very similar, as can be seen in Table 2.

Table 2. Average time for each exercise and total time in minutes. Exercise 4 is made up of 2 sections, so time is taken for each one.

#	Exercise 1	Exercise 2	Exercise 3	Exercise 4 p1	Exercise 4 p2	Total time
			AR Version			
Mean	0.71	2.45	3.13	5.11	4.52	5.35
Std. Dev.	0.50	1.36	1.58	2.37	2.12	2.20
			VR Version			
Mean	0.77	1.99	2.77	3.69	3.82	3.96
Std. Dev.	0.48	1.08	1.64	2.24	2.20	2.26

The results obtained from the second questionnaire are based on the User Experience Questionnaire UEQ [43] shows a more in-depth analysis and can be seen in Figure 10. The first aspect to be evaluated is to know if the system is attractive to the user, a significant result of 1.63 was obtained, which indicates that, for most of the students, the application was enjoyable.

Regarding the familiarization of the users with the system, a value of 0.78 was obtained, which indicates that it was complicated for the users to adapt to the handling of the virtual drone. As for the perceived efficiency of the system, a value of 1.31 was obtained, which is above the average value. Regarding the execution of the exercises by the users, the perception was high with a value of 1.95, which represents that the users were confident in using the system. As to whether they found the system exciting and motivating, the value obtained is excellent.



	Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation	Novelty
Excellent	0.64	0.47	0.6	0.8	0.8	0.89
Good	0.26	0.26	0.4	0.23	0.35	0.47
Above Average	0.41	0.52	0.44	0.33	0.35	0.39
Below Average	0.49	0.5	0.44	0.37	0.5	0.5
Bad	0.7	0.75	0.6	0.78	0.5	0.25
Lower Border	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
Mean	1.63	0.78	1.31	1.95	1.93	1.60

Fig. 10. Result of the evaluation of the user experience through the UEQ questionnaire for the Training Drone virtual reality environment.

Derived from this case study it was found that virtual environments can be a feasible option to represent scenarios in which users can perform various tasks such as learning to pilot a drone in a safe, playful, and motivating way that allows them to obtain a learning experience. The technological aspect is an important factor to consider since today almost all young people and adults have a smart mobile device capable of running complex applications, this gives the guideline to produce this type of new environments in which more scenarios for training are incorporated. Also, the evaluation of the user experience was an important factor to know in more detail the user and their preferences and perception during the use of the application. Carrying out this case study with university students helped to know the acceptance and interest in this type of applications since most of them had never interacted with a drone and those who had done so expressed their acceptance as it was very similar to the handling of a real drone.

7 Conclusions and Future Work

This work presents design elements under a proposed model for the production of virtual reality environments for drone pilot training. Among the aspects considered are the gamification approach, the design of the tasks to be performed, which are based on the exercises obtained from the existing aeronautical rules and regulations. In this work, the Mexican standard, the regulations of the AESA of Spain, and the FFA of the United States were taken into account, to identify the types of users to pilot drones as well as to identify the exercises for each type of user. The gamification approach helped greatly in the design of scenarios and strategies that can be incorporated at the time of producing these virtual environments and can also increase the motivational factor and the fulfillment of objectives within the virtual reality environment. As for the evaluation of the user experience, various instruments available in the literature and related works were analyzed and the UEQ questionnaire was chosen to be used in a case study to know the user's perception at the time of using the perception of use. It can be concluded as experiences obtained that:

- The proposed model can be used to produce virtual environments oriented to other user contexts where training and learning are required, for example piloting a drone for agricultural purposes, producing virtual scenarios to simulate search and rescue situations, among others.
- This case study allowed us to obtain feedback information for the improvement of the virtual environment produced for this case, we also got to know the general perception of the user and we tested one of the instruments for the evaluation of the user experience (UEQ Questionnaire) leaving the reference to propose new case studies in which other evaluation instruments can be incorporated such as AttrakDiff, CSUQ, among others.
- The proposal of two types of scenarios (VR and AR) within the application proposed in the case study left as learning that the elements can be reused under the proposed model, such as task design, gamification elements, even coding, but in practice with the user, the preference for the VR scenario was highlighted, since the AR scenario confused to the user at the beginning due to the mixture of virtual elements in a real space.

As future work we continue working on the incorporation of new exercises for professional and recreational users, incorporating new types of drones and generating new scenarios, as well as incorporating new strategies for evaluating the user experience that can provide feedback to the production of these virtual reality environments.

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