Development of an Augmented Reality System to Support the Teaching-Learning Process in Automotive Mechatronics

E. Fabián Rivera[1], Edison E. Morales[1], Carla Cristina Florez[2], and Renato M. Toasa[2](✉)

[1] Instituto Superior Tecnológico, Universitario Oriente, La Joya de los Sachas EC-220101, Ecuador
{frivera,emorales}@itsoriente.edu.ec
[2] Universidad Tecnológica Israel, Quito, Ecuador
{cflorez,rtoasa}@uisrael.edu.ec

Abstract. This article details the development of an augmented reality system to support the teaching-learning process, focused on the area of automotive mechatronics for gasoline vehicles. The application facilitates the user the interaction with the parts of the internal combustion engine in order to locate them in the assembly and disassembly process; in addition, the user can visualize the simulation of the thermodynamic cycle of the engine in improvements of the learning process. The geometric model of the elements of the Otto cycle internal combustion engine is made in CAD software, the development of the application and incorporation of the models and animations is done in Unity 3D. The execution of the Augmented Reality application during the pandemic originated by COVID-19 was essential to give continuity to the professional training process in the Automotive Mechatronics career, since the development of the teaching process was carried out solely online.

Keywords: Augmented reality · Automotive mechatronics · Teaching and learning processes · Unity

1 Introduction

At present, the world is going through a digital era, which has allowed the development of new technologies, such as virtual reality (VR), augmented reality (AR) and mixed reality (MR) [1], this has allowed the development of a combination of virtual space with a realistic environment to perform everyday activities, and the teaching-learning process is no exception, virtual models have been developed to support the education process, the work [2] affirms that: "The more realistic the simulation experience, the more intense the interactivity and perceptibility that can be provided", these 3D models are used to simulate real elements and students can visualize the objects, the closest as possible to reality.

L. T. De Paolis et al. (Eds.): AVR 2021, LNCS 12980, pp. 451–461, 2021.
https://doi.org/10.1007/978-3-030-87595-4_33

Since the beginning of 2020, the COVID-19 pandemic has impacted the entire world and forced schools of all backgrounds to close their doors and opt for virtual education. At the peak of the COVID-19 pandemic, which occurred in early April 2020, more than 1,484,715,875 students were affected worldwide [3], this caused some students to lose their learning, others to abandon their studies, in addition to the evident inequality due to the digital divide. In this sense, educational centers changed their teaching methods, where virtual and augmented reality of physical objects was less affected, since the virtual model allows simulating all the interaction between the student and the object under study.

In the educational field, 3D digital models facilitate the teaching of contents related to real objects such as buildings, vehicles, medical phenomena, etc., which can occasionally be complex and/or abstract for students [4]. In the industrial field, and even more so in the vehicle assembly area, 3D models are a fundamental tool for manipulating the different elements that make up the vehicle.

Several authors highlight the use of this type of technology in education and vehicle assembly. Initially Rivera et al. [5], presented the development of a training system in augmented reality; oriented to the teaching and learning process in the area of Automotive Mechanics for hybrid vehicles, the initial results show that there is a great acceptance by the users, improving the learning of work environments. On the other hand, in the work [6], a virtual training system for the recognition and assembly of automotive mechanics components is described, where the experimental results show the efficiency of the system generated by the human-machine interaction oriented to develop skills in the automotive mechanics area. In the automotive industry, several AR applications have been developed and analyzed to improve processes such as shortening production time, improving efficiency and saving production costs [7].

In reference to the learning process, the paper entitled "Augmented Reality and Virtual Reality in Education Myth or Reality?" [8], explains the reasons behind the new boom of AR and VR and why their actual adoption in education will be a reality in the near future, they mention that these radical changes and new models of teaching and learning must meet the needs of the 21st century learner, as their skills focus on cognitive, autonomous, collaboration and flexibility, and innovation aspects [9]. Finally, in 2021, a paper is published that develops an AR application to improve the teaching and learning process in Engineering Sciences [10], This application is validated with surveys to teachers, who detail the improvements obtained. Due to the COVID 19 pandemic, it cannot be fully implemented, but it is expected to be done in the coming months.

In this context, the present work proposes the development of an augmented reality system to support the teaching of automotive mechatronics. In this context, the animation and simulation of the thermodynamic cycle of the engine was carried out, in addition to emulating the process of assembly and disassembly of the gasoline engine in a three-piston Zotye vehicle.

The rest of the document is organized as follows Sect. 2 describes the formulation of the problem based on the needs of students who interact with vehicles in their teaching process, Sect. 3 presents the virtual environment and animation where the AR system, its architecture and the development process are detailed, Sect. 4 shows the analysis of the experimental results and finally the conclusions are shown in Sect. 5.

2 Problem Definition and Conceptualization

The COVID-19 pandemic poses a challenge to the socio-economic and educational system worldwide. Therefore, it is necessary to innovate with new tools for learning, and that is what technology should move towards, a new concept of education with virtual models that allow the user an almost real interaction of the different objects modeled, these specific aspects that affect the teaching process must be considered [11–13]:

Level of student and teacher satisfaction.

Experience in virtual models.

Types of tools.

Resource consumption by the system.

In this order of ideas, it is necessary to develop virtual AR or VR models to support the educational process, where both teachers and students have experienced a significant change in the academic process with these technologies.

As an initial case study, an AR system for the assembly of a vehicle will be developed for learning the subject of automotive mechanics and electronic injection.

Based on the above, it is necessary to determine the objects involved and that will be modeled for this article, it is important to first expose certain basic concepts of automotive mechanics.

2.1 Model Conceptualization

Use of three-dimensional geometric models (3D models) [14] made in software applying the fundamental principles of technical drawing, to obtain models close to reality is very useful for the development of auto parts, manufacturing industry in general. The use of this type of technology in the teaching-learning process has a positive impact because it helps the student to know and identify the elements that make up an internal combustion engine, in addition to recognizing the thermodynamic cycles involved in its operation, without the need for physical components. Among the advantages that can be mentioned, there is access to the teaching material without the need to be in a laboratory or workshop.

CAD software (Computer Aided Design) [15] is a computational tool for modeling three-dimensional elements through the use of operations and parameters.

The Geometric model proposed in this work requires four stages: (i) Selection of the working plane; (ii) Sketching of the two-dimensional geometry of the object. (iii) Dimensioning and insertion of geometric relationships. Creation of the three-dimensional operation. The first three stages correspond to the definition of the 2D sketch. The final stage is part of the three-dimensional definition, once the model of each of the components has been made; the assembly is carried out, which consists of joining each of the pieces to make a whole, see Fig. 1

For the purposes of this research, a model of an internal combustion engine is developed, which is a thermal machine that transforms the chemical energy of the fuel (gasoline) into mechanical energy (movement). It is called an internal combustion engine because the whole process takes place inside a cylinder.

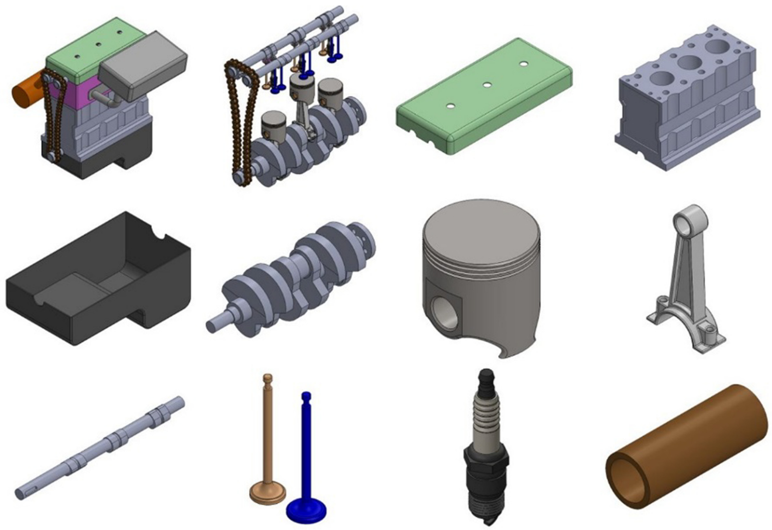

Fig. 1. Geometric model of Zotye Z100 engine elements.

Engine model developed consists of the following elements [16]: *i) Engine block*: It is the most important part of the engine, it is anchored to the body of the vehicle by means of an elastic joint, which is responsible for absorbing vibrations so that they are not transmitted to the body; *ii) Cylinder head*: It is the element that creates a seal with the upper part of the engine block, it is joined by its flat surfaces, between these there is a gasket, they are joined by people to ensure tightness; *iii) Piston*: The piston is the engine element that moves inside the cylinder with reciprocating linear motion, serving the cylinder as a guide; *iv) Connecting rods:* Its function is to transmit the movement of the piston towards the crankshaft, it transforms the linear motion into rotary motion; *v) Crankshaft:* It is the driving shaft that receives the force produced during combustion, through the connecting rods, this force is transformed into torque that is responsible for turning the crankshaft; *vi) Camshaft:* Its main function is to control the opening and closing time of the intake and exhaust valves; *vii) Valves:* These components are located in the cylinder head or cylinder head of the engine, their function is to open and close the air inlet and exhaust gas outlet orifices. The intake valve always has a larger diameter to give priority to cylinder filling.

An internal combustion engine produces work by performing cycles, which are detailed below, see Fig. 2. a) *Intake*: The piston has a downward movement from the PMS (Upper Dead Point) towards the PMI (Lower Dead Point), the intake valve opens and the air-fuel mixture enters; b) *Compression*, the intake valves close and the piston starts its upward movement, from the PMI towards the PMS the air-fuel mixture is compressed; c) *Explosion*: The combustion starts through the spark jump of the spark plug, product of the force produced by the explosion the piston has a downward movement from the PMS towards the PMI. The intake and exhaust valves are closed; d) *Exhaust*: The intake valve opens, the piston starts its upward movement from the PMI to the PMS, the gases produced in the combustion are expelled to the outside.

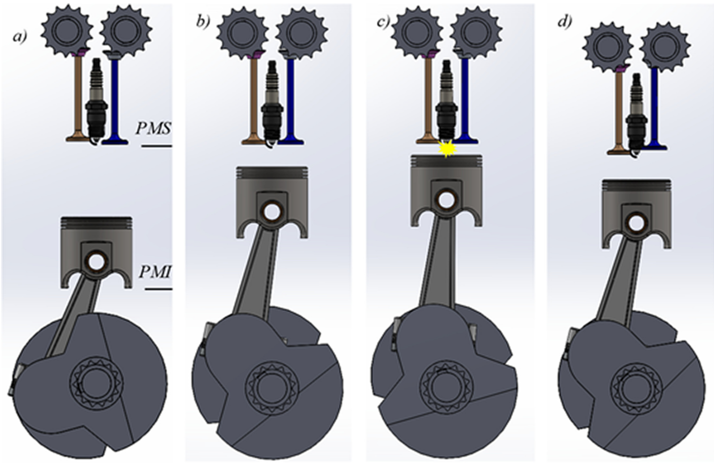

Fig. 2. Duty cycle Zotye Z100 motor.

3 Virtual Environment and Animation

This section describes the development of the augmented reality application, which consists of the following stages*: i) 3D Design Visualization; ii) Importing the 3D object into Unity; and finally, iii) Development of the training environment*.

3.1 3D Design Visualization

Vuforia Engine is used to facilitate the construction of AR-based applications which consists of an augmented reality-oriented development kit (SDK) for the Unity 3D video game engine. It allows the localization of virtual elements on real environments or objects. The visualization of 3D digital content in real environments is done using Ground Plane, since it allows placing digital models on horizontal surfaces and even locating content in the air by means of anchor points. To emulate the Ground Plane with the playback mode, the positional device tracker is used, the Ground Plane template must be used and positioned on a flat surface or even on the Zotye engine head as shown on Fig. 3.

3.2 Importing 3D Model into Unity

3D models of the Zotye vehicle engine components are structured in CAD-SolidWorks software. To import the engine and its elements developed in SolidWorks it is required to save the file in the extension (.IGIS), then using the 3ds Max program the model is imported considering the proportion, scale and use of materials for texturing as shown in Fig. 4, finally the model is exported using the extension (.FBX); since it has the characteristics of GameObject in order to place the object in the training scenes of the Unity virtual environment.

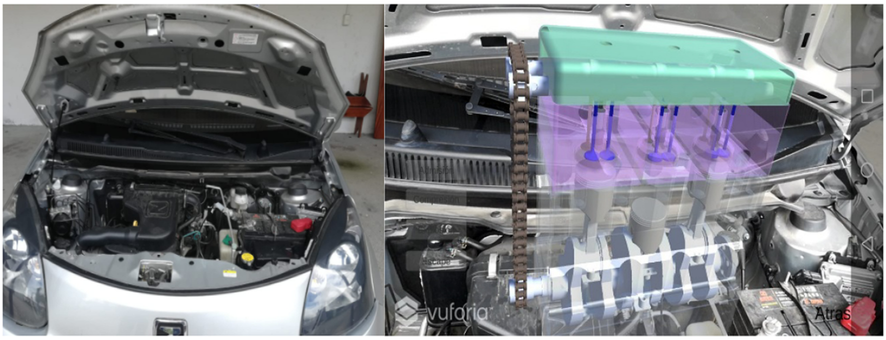

Fig. 3. Visualization of the 3D design on the Zotye head.

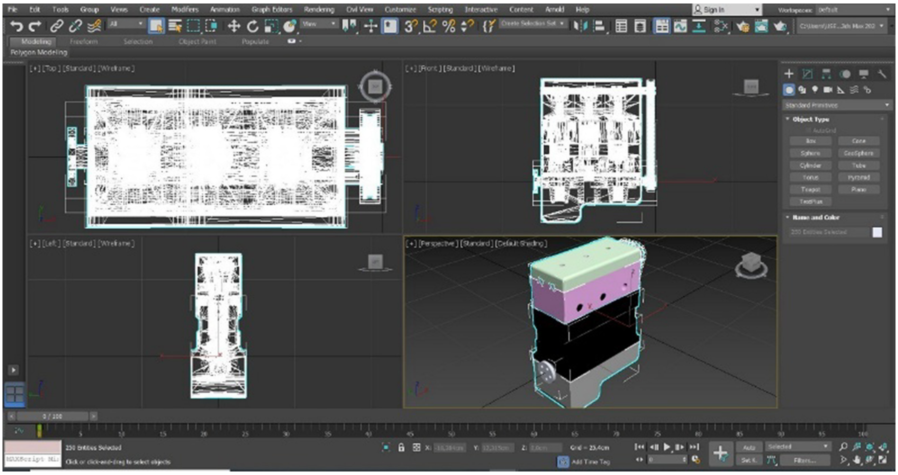

Fig. 4. Modeling in 3Ds Max

3.3 Development of Training Environment

The augmented reality system allows user interaction through virtual environments; in order to optimize training times in processes that require high costs for the assembly of large machines such as internal combustion engines; therefore, the training environment contains two scenes: i) Thermodynamic Cycle of the Engine, the development of the animations and the design of the frames is done in the animation panel of Unity; they are based on the operation of the engine of the Zotye vehicle. Additionally, to improve the control in the training scene, a script is designed to animate the change of states based on the thermodynamic cycles separately.

In Fig. 5. It is possible to appreciate the scene corresponding to the fuel intake, the simulation of the engine cycle driven by the virtual buttons. i) Explosion and Implosion, to perform the simulation of the assembly and recognition of the system parts, the Animator Controller is used (see Fig. 6), the animation clips are linked according to the parameters designed in the script, additionally the scene presents animations of position

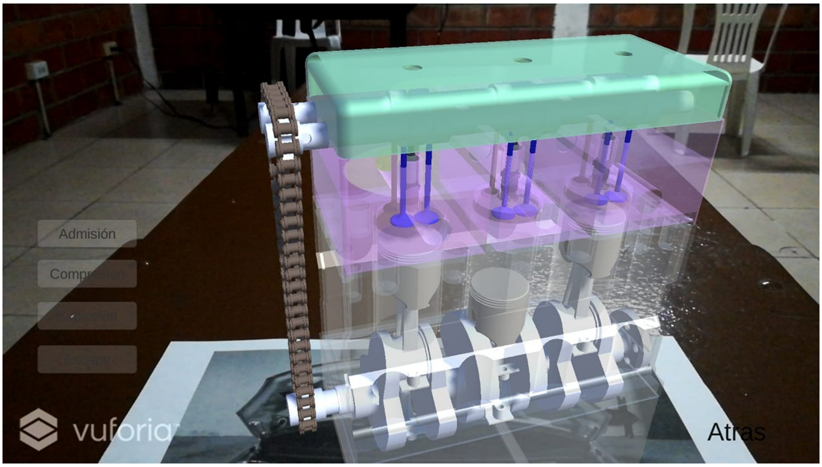

Fig. 5. Engine thermodynamic cycle scene

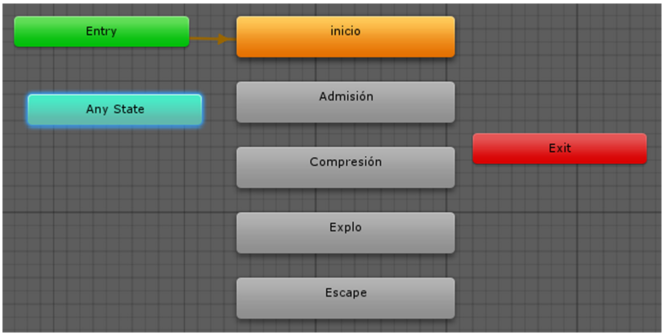

Fig. 6. Animator controller

and scale that allow identifying the parts and applications of the system separately, thus enhancing the interaction between the user and the system.

4 Experimental Results

This section is focused on the experimental results and operation of the augmented reality application, focused on the teaching-learning process with training in Automotive Mechatronics. Through the 3D simulation of the engine thermodynamic cycle, identification of its components and assembly of the system, resources are optimized, since the usual practical development demands time and cost of preparation of the system and its components.

For initial testing the application must be installed on an Android mobile device. At the beginning of the execution, the main menu corresponding to the training of the thermodynamic cycle of the engine and the explosion and implosion of the system is displayed as shown in Fig. 7, the access to the training scenes is done by pressing the virtual buttons.

Fig. 7. Main menu – RA system

The operation of the thermodynamic cycles is guided by animations to allow the user an intuitive and didactic handling of the system. In the simulation it is possible to appreciate processes that are not visible inside the internal combustion engine such as the fuel inlet through the intake manifold to the engine injectors, the opening and closing of the intake and exhaust valves, the thermodynamic cycles of the engine and the expulsion of CO2 through the exhaust manifold as shown in Fig. 8.

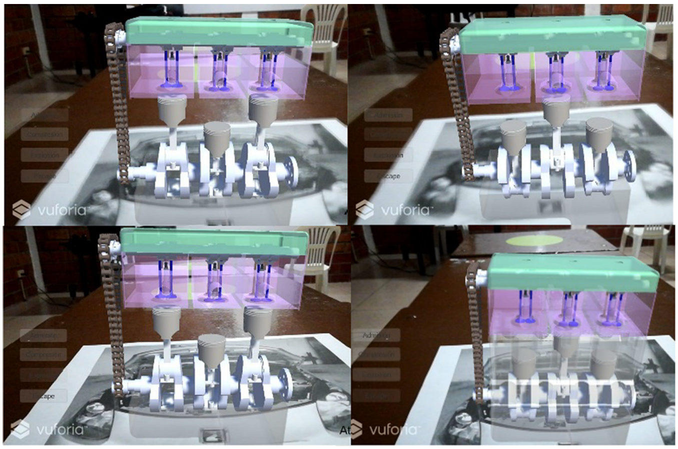

Fig. 8. Simulation of the engine thermodynamic cycle

In Fig. 9, the process of disassembly and assembly of the system can be observed. The purpose of the animation is to guide the user in the identification of the elements involved in the thermodynamic cycles of the engine, proceeding to identify each essential part of both the system and the engine, for example, the injectors, the intake manifold, the intake and exhaust valves, the engine block, the pistons, crankshafts, among others.

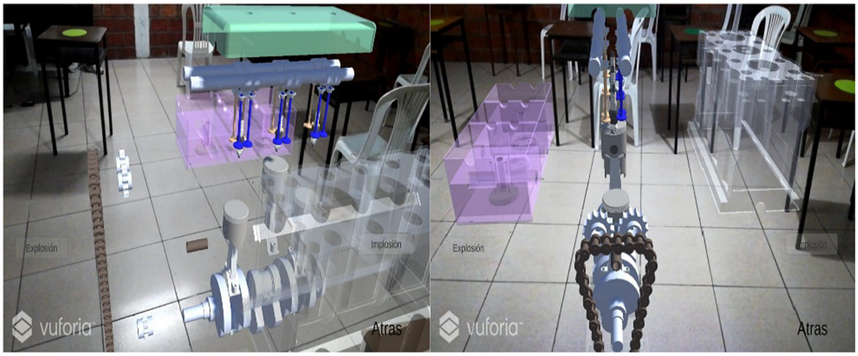

Fig. 9. Implosion system

To ensure that users (Students and Teachers) can use the AR system not restricted by a difficult user interaction, we conducted usability tests to evaluate whether:

The system is easy to use by the students.

The system is easy to learn, and the students are satisfied with the functionalities of the application.

To ensure the success of the application, the author should think like end users and anticipate the needs that exist.

To determine the usability of the system, a questionnaire of 10 pre-questions was applied, where the answers have a range of 1 to 5, 1 = completely disagree and 5 = completely agree. The method for evaluating the answers consists of subtracting 1 from the results of the odd numbered questions. The results of the even numbered questions are subtracted from the result of 5. The final result must be multiplied by 2.5 to obtain a value of 100%, see Table 1.

Table 1. Validation survey

Nº	Questions	Score	Operation
1	Do I need the guidance and support of an instructor to start the training?	2	5 – 2 = 3
2	Does the system help me understand the thermodynamic cycle of the engine?	4	4 – 1 = 2
3	Is the system applicable in homes considering virtual education?	5	5 – 1 = 4

(*continued*)

Table 1. (*continued*)

Nº	Questions	Score	Operation
4	Would you use the system to support the teaching-learning process?	4	4 – 1 = 2
5	Does the system provide the user with adequate physical security?	5	5 – 1 = 4
6	Do I consider the training system to be inconsistent or incomplete?	2	5 – 2 = 3
7	Does the system provide support to the development of practices considering the confinement by COVID-19?	4	4 – 1 = 2
8	Would you use the system frequently?	4	4 – 1 = 3
9	Do you consider that those processes that demand time in assembling and disassembling elements should be carried out in AR?	3	5 – 3 = 2
10	Is the system easy and intuitive to use?	5	5 – 1 = 4
			29

Table 1 shows the questionnaire applied to determine the usability percentage for the augmented reality system of the thermodynamic cycle of the Zotye vehicle engine, based on the analysis it was determined that the usability percentage is 72.5%.

The initial results are based on the teachers' comments, since due to the pandemic it has not been possible to validate it with students. In general, and according to the teachers' experience, they affirm that this AR system will allow a better understanding by the student in the area of automotive mechanics.

5 Conclusions

The use of the Augmented Reality application provides continuity to the teaching process in the area of Automotive Mechatronics, allowing them to improve the technical and practical training of users by immersing them in the analysis and simulation of the Otto cycle, as well as in the assembly and disassembly process of the gasoline engine.

The learning environment through the application minimizes the use of resources and preparation time, guaranteeing the learner a reliable and safe learning environment. The application is accessible to any user with a mobile device and Android operating system higher than 4.2.

As future planned work we establish the development of an electronic injection system of a vehicle by implementing the power supply system in conjunction with the sensors that govern the correct injection of fuel into the engine.

References

1. Williams, T., Tran, N., Rands, J., Dantam, N.T.: Augmented, mixed, and virtual reality enabling of robot deixis. In: Chen, J.Y.C., Fragomeni, G. (eds.) VAMR 2018. LNCS, vol. 10909, pp. 257–275. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-91581-4_19
2. Zhang, Y.: Development of WebGL-based virtual teaching platform for mold design. Int. J. Emerg. Technol. Learn. **13**(06), 16–28 (2018). https://doi.org/10.3991/ijet.v13i06.8581

3. UNESCO: Perturbación y respuesta de la educación de cara al COVID-19 (2021). https://es.unesco.org/covid19/educationresponse. Accessed 02 Mar 2021
4. Izquierdo Pardo, J.M., Pardo Gómez, M.E., Manuel, I.L.J.: Modelos digitales 3D en el proceso de enseñanza-aprendizaje de las ciencias médicas. In: Medisan, vol. 24, no. 5, pp. 1035–1048 (2020)
5. Rivera, E.F., Pilco, M.V., Espinoza, P.S., Morales, E.E., Ortiz, J.S.: Training system for hybrid vehicles through augmented reality. In: Iberian Conference on Information Systems and Technologies, CISTI, vol. 2020, June 2020. https://doi.org/10.23919/CISTI49556.2020.9141020.
6. Quevedo, W.X., et al.: Virtual reality system for training in automotive mechanics. In: De Paolis, L.T., Bourdot, P., Mongelli, A. (eds.) AVR 2017. LNCS, vol. 10324, pp. 185–198. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-60922-5_14
7. Halim, A.Z.A.: Applications of augmented reality for inspection and maintenance process in automotive industry. J. Fundam. Appl. Sci. **10**(3S), 412–421 (2018). https://doi.org/10.4314/jfas.v10i3s.35
8. Elmqaddem, N.: Augmented reality and virtual reality in education. Myth or reality? Int. J. Emerg. Technol. Learn. **14**(03), 234 (2019). https://doi.org/10.3991/ijet.v14i03.9289
9. Göksün, D.O., Kurt, A.A.: The relationship between pre-service teachers' use of 21st century learner skills and 21st century teacher skills. In: Education & Science ve Bilim, vol. 42, no. 190 (2017)
10. Nur Idawati, M., Enzai, N.A., Ab, M.A.H., Ghani, S.S., Rais, S.M.: Development of augmented reality (AR) for innovative teaching and learning in engineering education. Asian J. Univ. Educ. **16**(4), 99 (2021). https://doi.org/10.24191/ajue.v16i4.11954
11. Khanna, D., Prasad, A.: Problems faced by students and teachers during online education due to COVID-19 and how to resolve them. In: Proceedings of 2020 6th International Conference Education Technology ICET 2020, pp. 32–35 (2020). https://doi.org/10.1109/ICET51153.2020.9276625
12. Baek-Young, C., Sejun, S., Rafida, Z.: Smart education: opportunities and challenges induced by COVID-2019 pandemic. In: 2020 IEEE International Smart Cities Conference (2020)
13. Toasa, R.M., Baldeón Egas, P.F., Gaibor Saltos, M.A., Perreño, M.A., Quevedo, W.X.: Performance evaluation of WebGL and WebVR apps in VR environments. In: Bebis, G., et al. (eds.) ISVC 2019. LNCS, vol. 11845, pp. 564–575. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-33723-0_46
14. Jamali, A., Abdul Rahman, A., Boguslawski, P., Kumar, P., Gold, C.M.: An automated 3D modeling of topological indoor navigation network. GeoJournal **82**(1), 157–170 (2015). https://doi.org/10.1007/s10708-015-9675-x
15. "CAD Software|2D And 3D Computer-Aided Design|Autodesk. https://www.autodesk.com/solutions/cad-software. Accessed 14 May 2021
16. Escudero Fernández, S., Gonzalez Gonzalez, J., Rivas Cuadrado, J.L., Suarez Linares, A.: Motores Pk 2016. Macmillan (2016)