Virtual Reality System for Training in Automotive Mechanics

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Abstract. This article describes a virtual training system for recognition and assembly of automotive components is proposed. The system consists of a virtual reality environment developed with Unity 3D graphics engine, the same one that allows the user to have greater immersion in the teaching-learning process in order to optimize materials, infrastructure, time resources, among other benefits. The proposed system allows the user to select the work environment and the level of difficulty during the training process. The experimental results show the efficiency of the system generated by the man-machine interaction oriented to develop skills in the area of automotive mechanical.

Keywords: Automotive mechanics · Training system · Virtual reality · Unity3D · Modelling 3D

1 Introduction

Currently, the planning, definition, design, development and support processes of products in automotive area has evolved, in this way it has been necessary to improve the efficiency in each level of manufacturing vehicle's components [1]. Virtual reality is a technological tool with great potential in the automotive industry, allows the development of new prototypes in virtual environments, optimizing the resources of manufacturing companies. [2, 3]. The systems design that make up a vehicle such as: body car, cabin, power train, suspension, steering, brakes, to be simulated in virtual reality improves the productivity of the company, will allow to offer a system of training and efficient interactive training for after-sales staff [4]. Additionally, virtual reality can be taken to the commercial sector, where the customer can personalize vehicle in a virtual environment allowing to know the result of them acquisition [5].

The software CAD, CAM and CAE, used for the design and optimization of mechanical elements, are essential tools for engineering activities, because with them you can develop parts and components complex geometric with special specifications also simulate their behavior when are subjected to stresses and displacements of operation, which is necessary to determine its manufacturing process and actual application [6, 14, 16]. While these computational tools can predict the behavior of the different components that wish to make today there are proposals related to the area of

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Virtual Reality, VR, which allows active interaction between people and three-dimensional media, which will get a better study of parts designed [7, 8].

The Virtual Reality area has many applications focused on entertainment, education, graphic design, communication, medicine, automotive processes, aerospace engineering, among others [9, 15]; the training for the improvement of technician's skills in the maintenance and assembly area in the industry is fundamental to improve the technical capacities of operators [6, 10]. Through Unity 3D tool, which is software for creating 3D virtual environments [11], combining the Virtual Reality with the design software of the automobile's mechanical components, creates a virtual environment that allows to interact with new prototypes in which you can check designs and specifications.

In some institutions of higher as the University of Warwick in England education they have implemented interactive technologies such as virtual reality in vocational training, which has yielded great results in the teaching-learning process as it turns out to be an attractive alternative for students engineering undergraduate and graduate [12, 13].

In this context, the present article shows the development of a virtual reality application for the recognition and assembly of vehicle components, with the aim of creating a virtual environment as close to reality that facilitates the teaching learning process optimizing resources, for the Automotive Engineering students. To develop the proposal is used mechanical CAD design software, to model in 3D the internal components of the engine and the appropriate environment, in such a way that the environment is similar to an automotive workshop, to model the internal components of the engine in 3D, and the right environment, in this way the environment be as real as possible an automotive workshop, additionally the process results of identification and assembly of the engine components seen from the application of virtual reality are presented.

The work is organized into 6 sections including the Introduction. Section 2 presents a problem formulation in the manufacturing processes of the automotive area; the export of the mechanical components developed in CAD software to virtual reality are presented in Sect. 3. Section 4 develops the virtual environment that allows a user immersion in automotive training and learning processes. The experimental results are presented in Sect. 5; while the conclusions are shown in Sect. 6.

2 Problem Formulation

Actually, the automotive industry for vehicle development involves the following levels of processes; definition and planning of the project, definition of specifications, conceptual design, product development and product support; in the fifth level of the process is the support level to the product in which other phases such as: supplier support, maintenance, customer support and manufacturing and assembly support; the main objective of this level is to provide the necessary assistance to the product developed in this case to the manufactured vehicle and is used by the customer through a suitable after-sales service with maintenance programs that allow to optimize the characteristics of the vehicle.

This paper aims to identify the components and facilitate learning both the assembly and operation of the various components that make up the vehicle, both from their external systems and internal elements, in a virtual reality environment [19]; which will allow students to increase their theoretical and practical skills, achieving learning outcomes in an interactive way that will be put into practice in their professional life, in this way contributes to solve problems in the maintenance area contributing to the product support level, the manufacture processes of a product aligned to the automotive industry are shown in Fig. 1.

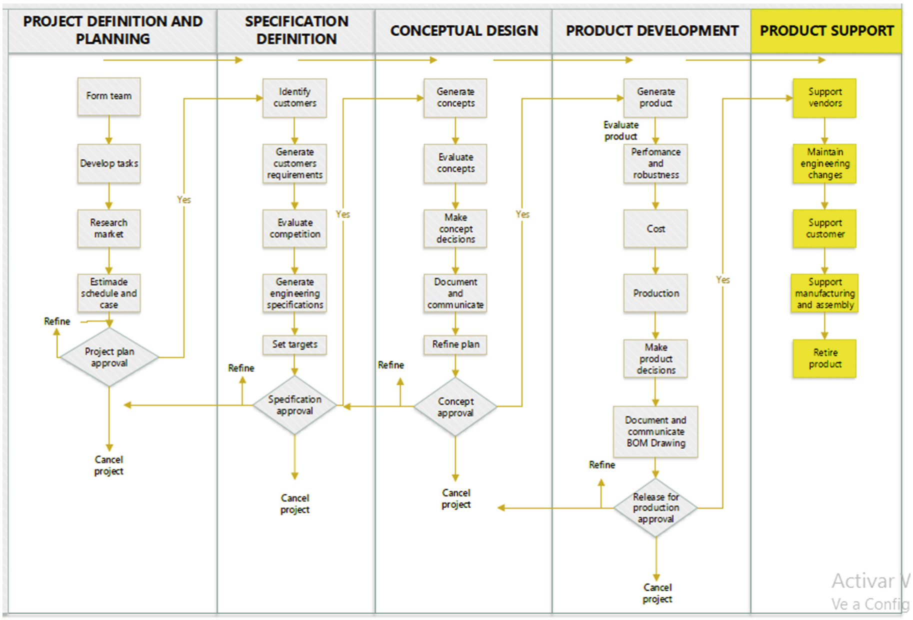


Fig. 1. Diagram of design process [17]

The application will allow to work in any of the vehicle's mechanical systems, such as: body car, cabin, power train, suspension, steering, brakes; allowing an interactive innovation of virtual reality in the manuals of technical service, which would allow the technicians to solve problems in a more efficient way, in the after-sales process.

The virtual reality area in the automotive manufacturing industry, can be included in the other levels of the process as: conceptual design and product development, with the help of tools as CAD, CAM, CAE and virtual environments, would optimize processes by reducing design times [6].

3 System Structure

The scripts of control are developed, to respond to the operation of different process associated to the virtual device in the Unity environment, Fig. 2.

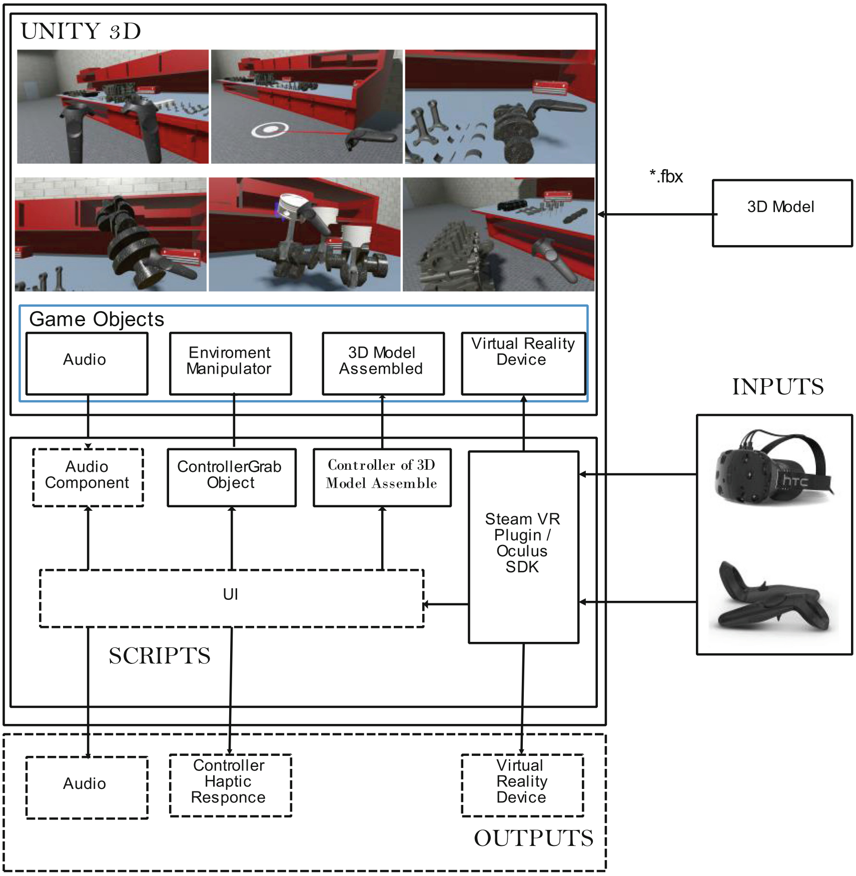


Fig. 2. Component interrelation diagram

The simulation phase of the scene, contains all virtual reality programming, where the components of the 3D model and the assembly controller used are linked, in this phase it's found the necessary configuration as the physical and coupling properties that simulates an assembly process identical to the real.

In the input and output phase can be considered several devices that allow to observe the virtual environment as: helmets of virtual reality (Oculus Rift, HTC VIVE and GearVR) and haptic input controls that allow to interact with the environment within which it can be considered the novint falcon, tracking hands devices (Leap Motion, Manus VR, Myo Armband, HTC VIVE). The use of different input and output devices in the desired application requires that the code structure be general, so that it is compatible on several platforms, without the need to reconstruct the project, and automatically detect the aforementioned devices.

The SCRIPTS stage manages communication with each of the input and output devices, providing the virtual environment with the functionality required, Additionally, to implementing the interface where the user is allowed different ways of interacting with the application, showing the different levels of difficulty in which the subroutine of the controller can be used to manipulate the objects of the environment with a sound response, using the algorithm based on the model's component hierarchy. Finally, the output stage provides the user surround audio 360, haptic response to the inputs, and visual feedback to the tracking of user movements within the virtual environment.

4 Machine Virtualization

The design of any equipment or element starts in a CAD software, this software is a parametric tool of solid modeling based on operations that takes advantage of the facility of learning of the graphical interface. For example, SolidWorks is a tool that allows you to create 3D solid models, in which you can see in detail its shape and its component parts, in addition that allows to realize kinetic analysis of the forces that interact in the created models [19].

In this paper, we propose a multi-layer scheme for the development of applications in virtual environments in order to provide a greater immersion to users in training tasks in the area of automotive mechanics. *(i) Layer 1*: Is responsible for importing 3D models created in CAD software; *(ii) Layer 2*: in this layer is determined from the reference system and establishes the hierarchies of each of the parts of the 3D model; and finally, *(iii) Layer 3*: the interaction between the virtual input devices and the environment where the application is executed. In addition, the evaluation phase of the training performed by the user is implemented in order to evaluate the knowledge and skills acquired with the application developed, see Fig. 3.

To import the 3D models developed in a CAD software to the Unity3D graphics engine it is necessary to previously use the software 3ds MAX, in order to establish the hierarchy of the parts of the model [18]. The hierarchies are established according to the assembly of the machine or modeling equipment, it also depends on the number of elements and the position constraints of each element according to the model. For the orientation and location of the parts of the model, the reference points (Pivot) are determined; At the end of this process you get a *.fbx file compatible with Unity3D in which the virtual environment application will be developed.

While in Layer 3, the configuration of inputs for the interaction of the moving parts that make up the 3D model and the user interface using HTC VIVE and Gear VR devices, is performed by using functions of OnTriggerEnter, OnTriggerStay, OnTriggerExit. For the manipulation of the object (moving part of the model) the GRIP or TRIGGER button is considered, emphasizing the collider of the object. While for the user's movement in the virtual environment, "teleportation" is implemented, which

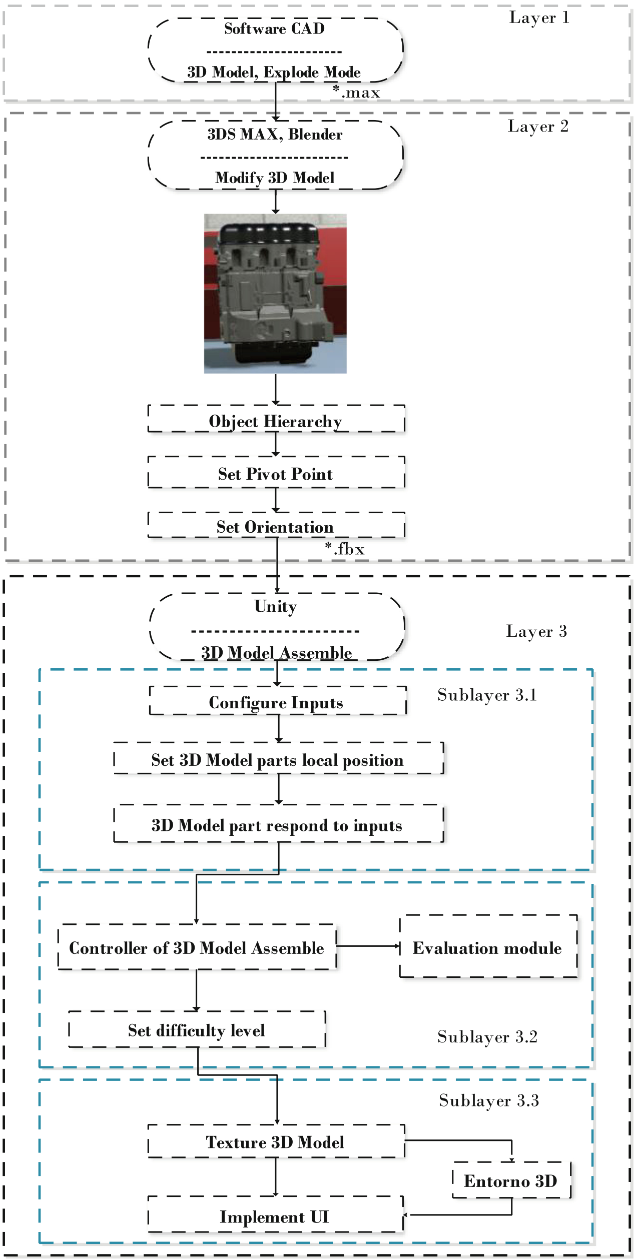


Fig. 3. Virtualization model

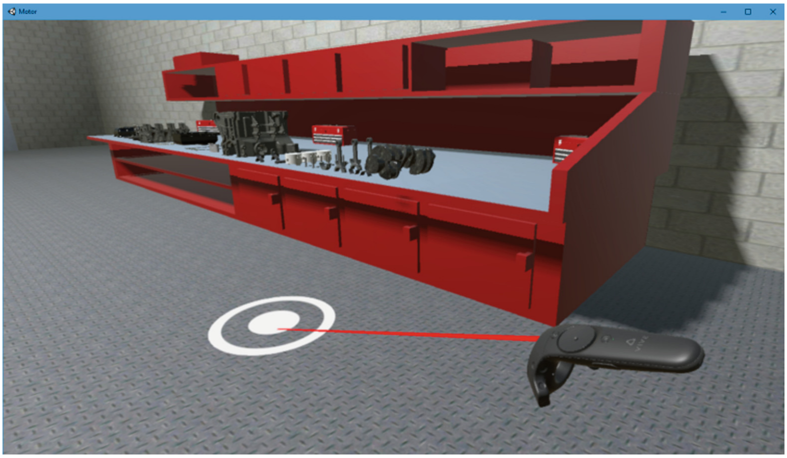


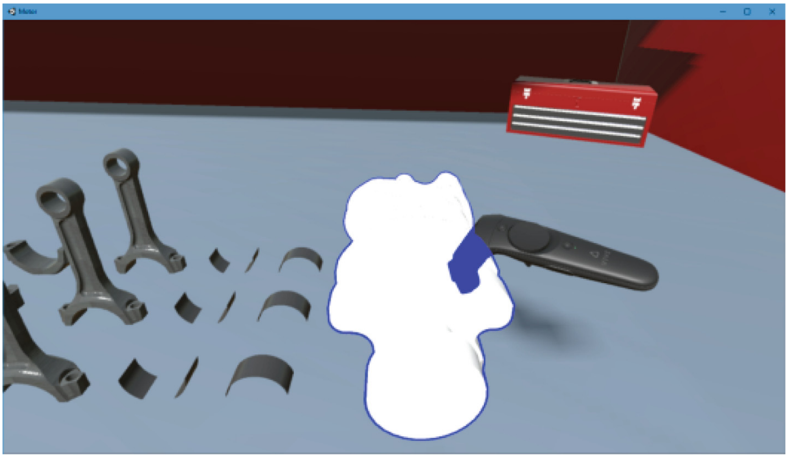
Fig. 4. Use of teleportation

consists in pointing a reference point on the surface for the purpose of transferring a desired point to the user, see Fig. 4.

In the second sublayer, the local position of each of the parts and pieces is recorded in relation to the original 3D model, in order to make a comparison between the correct position and the position in which the user locates the object. In case that the manipulation of the object is nearby of the correct position, an outline is shown for the purpose of guiding the user in the assembly process. For gripping the object, you must configure the response that each object will have to the input stimulus already configured previously, when the input device collides with a GameObject, *i.e., a*sks if your tag is of type "objects" the material of the object changes to a material that denotes selection (white body and blue outline), see Fig. 5.

In the third sub-layer the application drivers are developed, starting with the control of assembly of the 3D model. For the assembly, the original model of the object is used which makes its components invisible - with the function MeshRenderer, allows to activate again according to the correct position of the object manipulated by the user, see Fig. 6. This controller interacts with the evaluation module, designed to weight the test result, considering the following variables: time, difficulty, and correct positioning of objects (in this case, the outline help is disabled in the correct position of the object). The difficulty level selector edits the assembly controller parameters in order to vary the strength of the test.

Finally, the last sublayer focuses on the development of the virtual application environment and the texturing of each object considering the real characteristics, e.g., Color-texture-rigorousness of the object through albedo, metallic, normal and height map, obtained from an original image. In case it is not possible to obtain textures directly from the actual model, it is recommended to use Substance Painter to approximate the texture to a real state of the model. In order to allow a greater immersion of the user in the virtual environment, an environment according to the task to be executed is developed, compatible with the mobility and movement of the user



(a) Select object

(b) Object grip

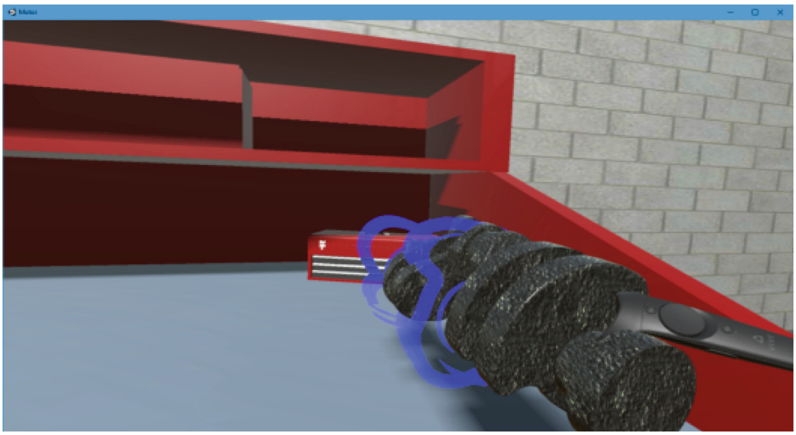


Fig. 5. Handle object (Color figure online)

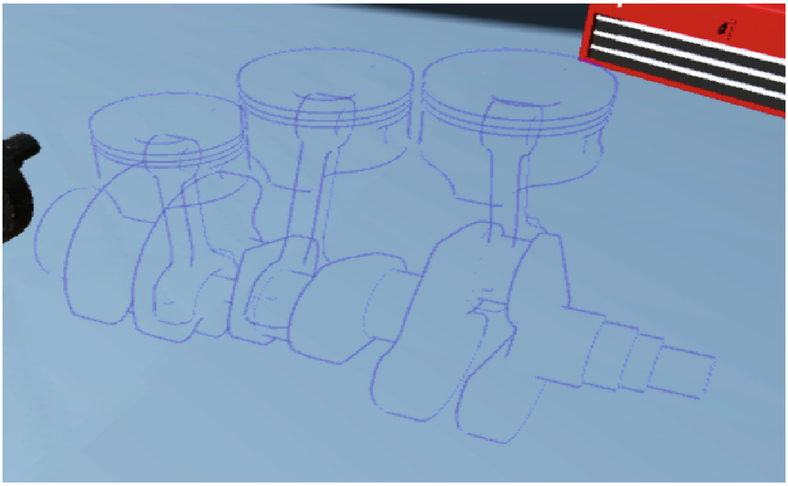


Fig. 6. Control assembly

(configured in the input of the devices) as tele-transportation and walking in the case of HTC VIVE, in which also sound response is added in each GameObject considering type of material when colliding: metallic, plastic, concrete, and feedback in the assembly and in the user interface.

5 Results and Discussion

In this section, we present an immersive virtual environment, see Fig. 7, of a workshop of automotive mechanics, in which a dynamic environment is developed so that the user can interact in a more real way with the proposed application.

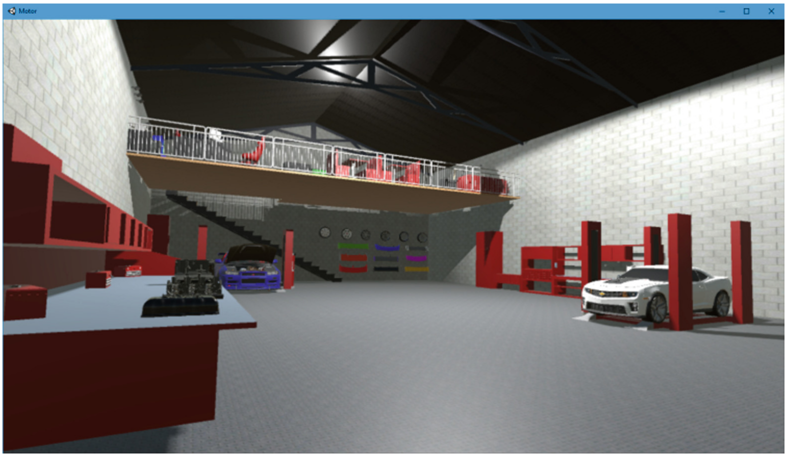


Fig. 7. Virtual environment of the automotive workshop

Fig. 8. Test vehicle

The application allows assembly of the entire vehicle Fig. 8, according to the level of knowledge of the user, the application has different modules or assembly sections of the mechanical part e.g. transmission, brake and motor; in a similar way has different levels of difficulty depending on the number and detail of the parts being considered for a specific test e.g. bolts, nuts and bolts.

For this work is considered an internal combustion motor and ignited provoked, of the vehicle Suzuki Forsa, Fig. 9, of three-cylinder in line, the elements considered for the present project are, mobile components: camshaft, crankshaft, valves, pistons, connecting rods, wheels; fixed components such as the engine crankcase.

Initially an environment is shown where the motor is disarmed and the parts and pieces that make up it are on a work table, Fig. 10.

The main objective is to assemble the motor in an orderly manner, placing the available parts in the correct position. For this the PC platform and the HTC VIVE device are used with their controls. The first step is to access the application and perform a recognition of the place and the input methods designed. To get close to a nearby place, walk to the desired place, if you want to reach an end of the room you need to press the touchpad of the remote and choose the desired location using the pointer that moves on the floor.

To select a part, simply carry a control to the desired object, in response you will get a color change that confirms that we are enabled to choose that part, to take the selected piece the TRIGGER button, as a visual response, there is the color change of the piece to its original texture as indicated in Fig. 5. To move from one place to another, the TRIGGER button is held down, to release the part at the desired location, the TRIGGER button is depressed (Press Up). It is advisable not to release the part if it is colliding with another. To select the correct part location, in the engine assembly,

Fig. 9. Motor model used in the application.

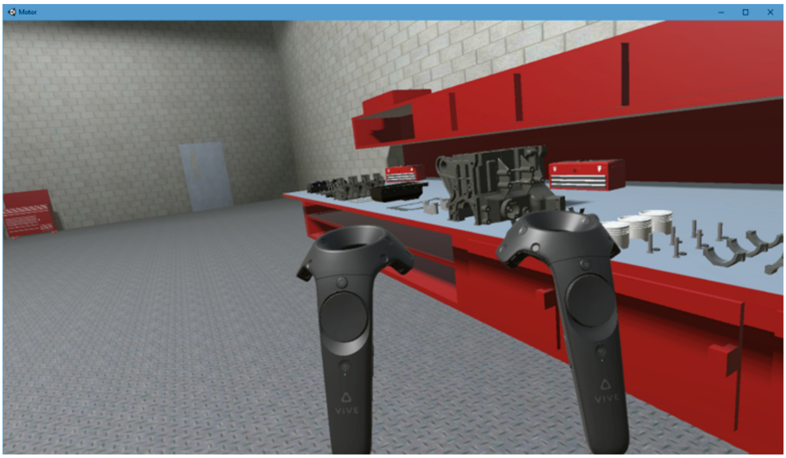


Fig. 10. Virtual work table

proceed to search for an approximate location until a outline that has the shape of the piece in the correct location, The system will accept the embedding of the part regardless of whether the part does not have the correct rotation or orientation at the time of detection, see Fig. 11.

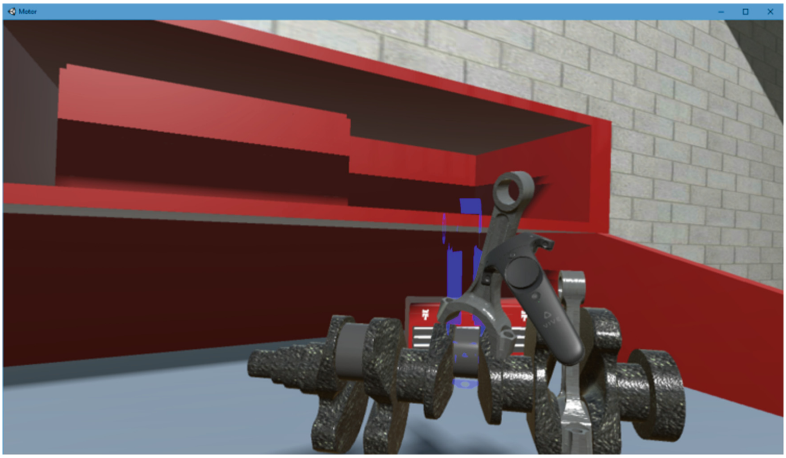


Fig. 11. Assembly of connecting rod to crankshaft.

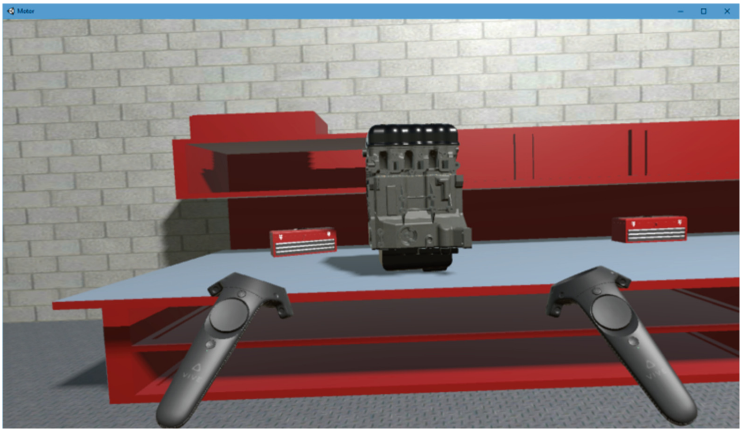


Fig. 12. Final motor assembly.

The user has the option of taking the motor assembly and rotating it or locating it according to its criterion to facilitate the embedding of parts. While running the test, it is possible to teleport with one control, while with the other you can hold the part or assembly of the motor. At the time of completing the motor assembly Fig. 12. you can see the statistics: time used, correct position of the pieces, difficulty level chosen and the option to redo the task.

6 Conclusions

In this paper, a virtual training system for automotive mechanics is proposed. The system consists of a virtual reality environment developed with graphic engine in Unity 3D. The same that allows the user to have a greater immersion during the teaching-learning process in order to optimize material resources, infrastructure, time and other benefits. The experimental results obtained show the efficiency of the system generated by the human-machine interaction oriented to develop skills and abilities in the area of automotive mechanics.

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