MAINTENANCE AND INSTRUCTIONS FOR VIRTUAL REALITY SYSTEM ASSEMBLIES[1]

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Miguel Beteta Lara[2], Victor Inácio de Oliveira[3], Rogerio Issamu Yamamoto[4], Marcones Cleber Brito Van Silva[5], Anderson Alves de Oliveira[6], Ricardo Janes[7] and Peterson Carlos Pirola[8]

ABSTRACT

The main objective of this work is to create an integrated environment in virtual reality for simulation of maintenance processes, prototyping and assembly of customized industrial automation sets. For this, an application was developed using the UNITY software. The model was tested and simulated for various types of assemblies, using elements such as pneumatic cylinders, compressed air handling units and process automation valves. The results show that it is possible to create a new way to teach workers and students to adapt to these machinery and equipment, concluding a way to optimize future learning and instruction processes to facilitate the maintenance of components of a company and didactics of new members in the world of industrial automation, in addition to contributing to the advancement of technology and development of industry 4.0.

Keywords: Virtual Reality. Industry 4.0. Industrial Automation.

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[2] Mackenzie Presbyterian University
[3] Mackenzie Presbyterian University/Salvador Arena Engineer College
[4] Mackenzie Presbyterian University/Salvador Engineer College
[5] Salvador Arena Engineer College
[6] Salvador Arena Engineer College
[7] Mackenzie Presbyterian University
[8] Salvador Arena Engineer College

INTRODUCTION

In the current global context, several companies need to achieve competitive growth to continue standing out in the market, in which this advance often involves the use of new technologies for process improvements and employee qualification. For Netto *et al* (1998, p 104), it would be necessary to replace obsolete and low-productivity equipment with more modern and productive ones, with restructuring of factory *layouts* and existing transport flow.

In the advancement of history, several artists and authors of characteristic works sought ways to portray the world and reality according to their own senses, but only achieved a great advance with the use of 3D perspective, where it was possible to create a progression to new notions of space and movement (LAVALLE, 2023).

The form of modern industry, called Industry 4.0, has as its main objective to maintain the man-machine relationship present in the process, to the point that it is possible to continue the exponential development with technology and conceptions of human understanding to facilitate general processes and incorporating the realistic perspective in the process.

According to Braga (2001, p5), the area of education is the sector where there is a greater focus on the introduction of new technologies, in which it can be seen as a process of discovery, exploration and observation. Multiple experiences may facilitate users with a new, more advantageous and expansive learning, allowing traditional methods to be modified and improved as studies advance. Thus, it would be possible to incorporate the studies with this new revolution of industrial improvements, allowing a great advance in both areas with a correlation that can further facilitate the growth of new technologies in the market of industries that wish to have an expansive increase in their competitiveness.

According to Casas (1996), research in the construction of intelligent education environments has been underway for almost three decades in which the main focus is the individualization or adaptability of the user in the involvement of interactive systems. The operation of any machinery or set requires the preparation of operator training, but it is often not possible to carry out this training due to various factors such as costs, lack of practicality and space, safety risk, and others (BUCIOLLI, 2006). Virtual reality systems provide a constant and coherent reaction to users' movements, making a consistent experience possible to enjoy a sense of presence in the virtual world (BOTEGA, 2009).

The work developed is of the modeling and simulation type.

The objective is to develop an integrated environment in virtual reality with 3D object simulation in order to use this technology to teach and improve industrial processes, to the point of teaching employees and instructing students the handling and assembly of assemblies used in industrial automation processes.

The expected product is a 3D environment, with six degrees of freedom, capable of simulating assembly instructions and interaction with components, created by the UNITY software, with fundamentality in the development of the competitive advancement of companies, as well as progress in the area of technology aiming at the future of the automation industry.

LITERATURE REVIEW

The great challenge is to create a constant simulation of machines and industrial assemblies due to the implementation in the field of simulations and animations, with synchronization of stages, but it facilitates the understanding of the use of devices by observing from different angles of the process of a real machine, including those that are difficult to access or almost inaccessible (BUCIOLLI, 2006).

Virtual reality simulations are part of a new context that characterizes this revolution to change and transform the industry through digitalization, opening doors for the entry of new technologies widespread in this type of innovation.

The objective of this work is to develop an environment that allows interaction with 3D objects and enables the various personalized applications with assemblies generated by the integration of virtual reality.

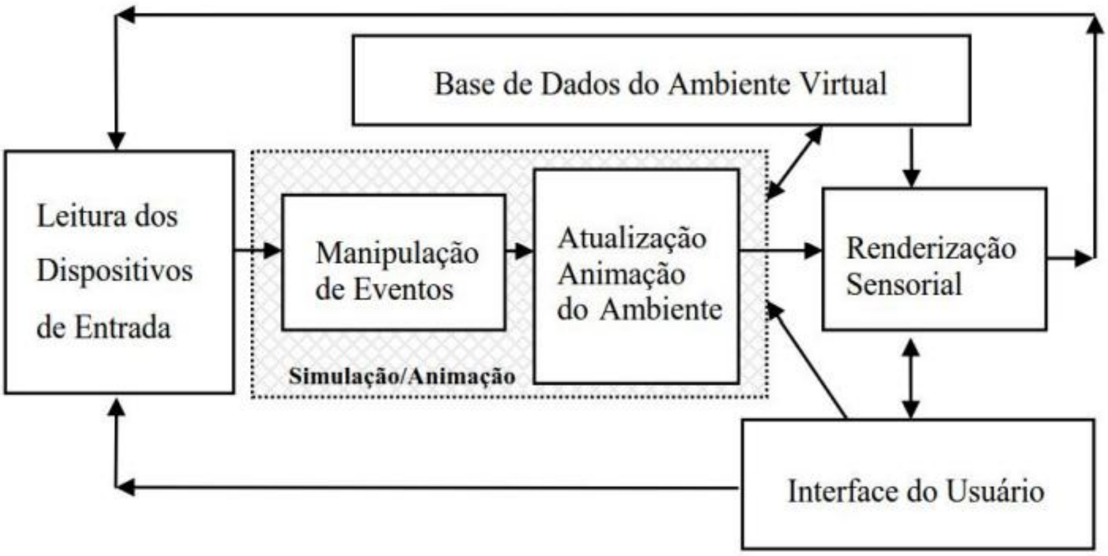
OPERATION OF DEVICES IN VIRTUAL REALITY

Virtual Reality (VR) can be described as an advanced user-computer interaction interface, as it uses different realizations of devices and peripherals with multisensory actions with aesthetic similarity of the real and physical environment (BORBA, 2021, p.754). This technology is capable of transporting the user to the simulation environment, allowing him to interact and feel fully immersed in a virtual world, capable of feeling reactions and interacting with objects (KIRNER, 2011).

This new technology is capable of introducing the user to various information through a processor that is capable of computerizing data so that there is a simulation of an environment capable of allowing the user to interact with what he is viewing. For this, a resource capable of creating a greater illusion of depth is used, making the user feel this perception from their own brain through their own senses in an environment totally recreated from computer modeling, which differs from Augmented Reality (AR), which uses the real medium to create this perspective.

In this virtual environment, it is possible to make people able to have expanded meanings of intensity, making it possible to see, hear, feel, activate and travel in a space with greater or lesser perceptions of depth, observing various occurrences and phenomena (TORI *et al.*, 2006, p.10). With this, data is read by sensors that perform event manipulation and create a basis for them to render and simulate the desired environment, from the interface between user and machine. Figure 1 shows what the diagram would look like for this cycle of data input and output from the device.

Figure 1 – System architecture diagram



Source: (Tari, Hounsel A. Kiron's 2018).

INDUSTRY 4.0 AND NEW TECHNOLOGIES

According to Santos (2018, p.2), "Industry 4.0 is one of the terms used to describe the high-tech strategy promoted by the German government that is being implemented by the industry". The introduction of new Internet technologies in industry can be seen as the great technological basis for Industry 4.0 (PEREIRA; SIMONETTO, 2018, p.2). This new industrial model allows new forms of production to be adapted so that in the future it will be possible to maintain a human-machine relationship present throughout the system, to the point that we can optimize processes and improve overall performance.

For Coelho (2016, p.18),

> The impact of industry 4.0 goes beyond simple digitalization, passing through a much more complex form of innovation based on the combination of multiple technologies, which will force companies to rethink the way they manage their business and processes, how they position themselves in the value chain, how they think about the development of new products and introduce them to the market, adjusting marketing and distribution actions.

The innovations that will be adopted in this new type of revolution demonstrate how important it is for us to have a significant evolution in the market, due to the various improvements present in the scope of this new model. According to Klaus Schwab (2017, p.3), there are three reasons why this new revolution will take hold: Speed (with a multiple exponential result due to the worldwide interconnection by new technologies capable of performing this type of characteristic), breadth and depth (results beyond industry, predicting improvements in the economy, society and business) and impact systems (transforming the relationships between systems, companies and countries as a whole).

Industry 4.0, therefore, is a large set of new technologies in growth for applications in the social environment of work and production. Among these technologies, examples such as virtual reality, augmented reality, artificial intelligence, nanotechnology, Internet of Things[9], automated vehicles, 3D printing, and others can be obtained. The combination of these technologies has the potential to enable the so-called *Smart Factories* [10](JUNIOR; SALTORATO, 2018, p.4).

According to Hozdić (2015, p. 4), a smart industry is an industrial solution that provides flexible and adaptable production that solves problems with fast and dynamic speed to change the complex conditions of the world. To reach this level, globalization allows us to create opportunities and improvements from technological advancement and thus introduce new methods of research and development in modern industry.

Collaborative virtual and augmented reality environments open up new possibilities for group collaboration (PRESTES; CLETO, 2019, p. 6). Industry 4.0 benefits from exploring these environments so that it is possible to collect data and encourage industrial practices remotely and interactively.

VIRTUAL REALITY IN THE TRAINING AREA

For LaValle (2023, p. 13), a first-person experience can revolutionize several areas of knowledge, including engineering, mathematics, and science in general. Virtual reality offers a solution for concepts of geometric dimensions and interpretation of more complex data, in order to be able to naturally develop learning from the use of this technology. In this sense, the importance of a need for the link between sectors of technology development and the area of education is perceived (PEDROSA; ZAPALLA-GUIMARÃES, 2019).

Virtual Reality will be a great advance for the way new students learn or for different occasions, such as factory operators, however, the process may be a little slower than

[9] Term that portrays the digital interconnection of objects with the internet, enabling data collection.
[10] Industries that have interconnected tasks between employees and machines with data collection and digitalization.

usual due to the insecurity of using this new equipment. According to Borges *et al* (2019), "only 18% of companies in high-performing industries are ready to act, according to surveys, while 29% are not fully prepared and 30% are only somewhat prepared". The big question is to highlight the benefits according to the entry of the simulation of environments in the market and in other sectors.

The training area will benefit the most due to the great benefit of the use of immersive technology with the ability to continuously improve processes. Within this area, not only teaching for didactic use stands out, but also the integration procedure for improving functionalities, such as in the health area.

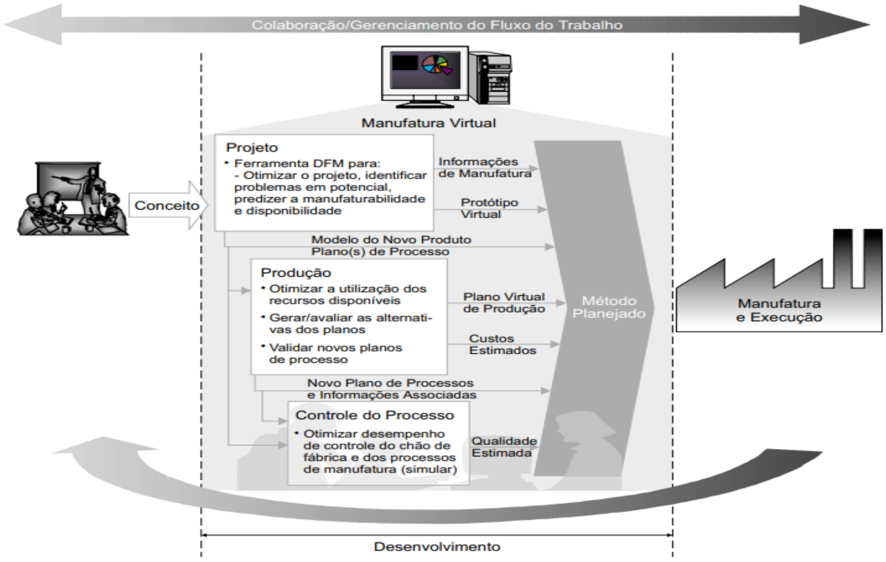
Lopes, Myskiw, Bós, Oliveira, Perpétuo, and Souza (2021) conducted a study with elderly people of different ages to use Non-Immersive Virtual Reality (VRNI) games, as training to stimulate functionality, showing in their studies that it is possible to use this technology as a safe physical intervention option, especially in tasks such as Palm Pressure Strength (PPF) tests, which significantly increased a difference from 21.1 ± 12.60 kg to 23.8 ± 13.51 kg. The same use of this technology allowed people with Parkinson's disease to be trained in virtual simulations. Among the various methods of motor rehabilitation, Virtual Reality can favor the use of motor training improvement, creating main benefits to learning through adequate training (SILVA *et al.*, 2019).

VIRTUAL REALITY IN THE INDUSTRIAL AREA

Virtual Manufacturing is understood, according to Porto, Souza, Revelli and Batocchio (2002, p.2), as a diversity of industrial processes and systems, defined as a modeling of systems and components by computers, audiovisual devices and sensors for the simulation of projects or environments in order to prevent real problems and inefficiencies. This concept has existed since 2002 and has played a fundamental role in providing an opening for the use of technologies in the industry.

It is noticeable that it is very similar to the use of Virtual Reality, since it integrates in its conception, the idea of creating a proper environment for simulation and verification of processes capable of improving or benefiting current procedures. Figure 2 shows an example of how virtual manufacturing would work by integrating computational processes and new technologies in the market in order to improve industrial processes.

Figure 2 – Virtual Manufacturing Environment



Source: (Porto, Souza, Ravelli, Batocchio (2002) based on the study by Porto and Palma)

For Netto, Machado and Oliveira (2002, p.26), the virtual environment can be applied in prototyping, which facilitates the product development cycle. As Virtual Reality guarantees the use of six degrees of freedom, it is possible for the operator or user to have better process control when verifying the prototype of items or assemblies as they are integrated into the simulated environment.

In the field of ergonomics[11], Virtual Reality can be an addition to the implementation of industrial processes with support for the evaluation of the operator's posture in the work field, allowing speed and instant optimization in a simulated station (WATANABE; CAPATAN; SIERRA, 2023). The introduction of virtual environments can be useful for users to adhere to an improvement in the way they behave during operation, thanks to the simulation of this same system.

Therefore, the effectiveness in the use of Virtual Reality can be useful so that several areas that require didactic and industrial can benefit from the use of the new technology, to the point of developing a new educational method of didactic and immersive training.

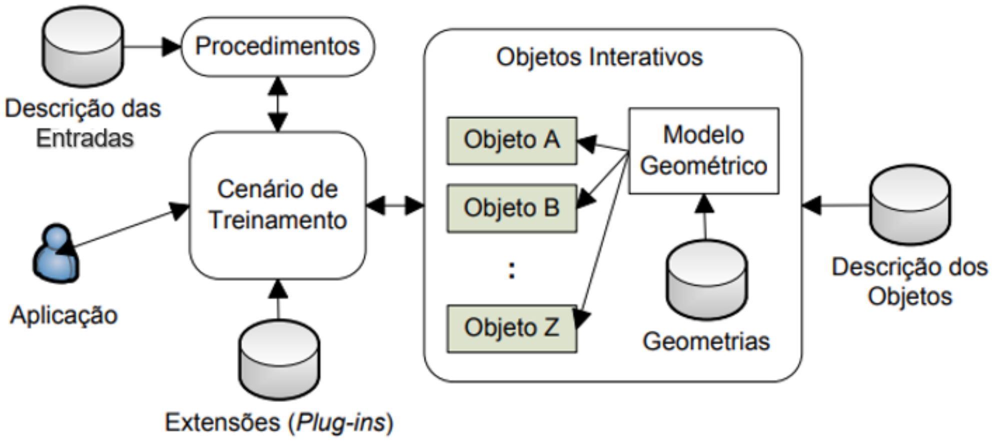
METHODOLOGY

In this project, an environment was created for learning about maintenance and instructions for assembling systems in virtual reality. For this, the methodology axes were divided between the use of software to create the environment, development of *assets* to adapt the environment and application in virtual reality hardware, which were broken down into three stages: training scenario, interactive objects and application. Figure 3 presents an

[11] Science that aims to understand the collaborative work between machines and human beings.

overview of the operation of the system from a graphical flowchart of the application of the scenario.

Figure 3 - Architecture Overview



Source: (Belloc, 2011)

The first phase of the project corresponds to the development of the setting and configuration of the virtual reality scenario for the training. In this stage, the development of a small prototype of a video game in a 3D environment was applied, as shown in figure 3, with application for software configuration in order to adjust the specific parameters for the use of virtual reality. The game was made using the . DXF and . FBX imported into UNITY 3D (CUPERSCHMID; RUSCHEL, 2013) in order to search for files and models with free and fast access. These files were obtained through UNITY's own template website, called the *Unity Assets Store*.

In this store, it was possible to download *assets*, such as textures, models and projects to facilitate the procedure and development of projects on the platform. The UNITY engine[12] allows these resources to be easily added and can be transformed into a 3D setting. In this model, a game object is specified through the composition of several functionalities, which are added (or removed) (PASSOS *et al.,* 2009, p. 9).

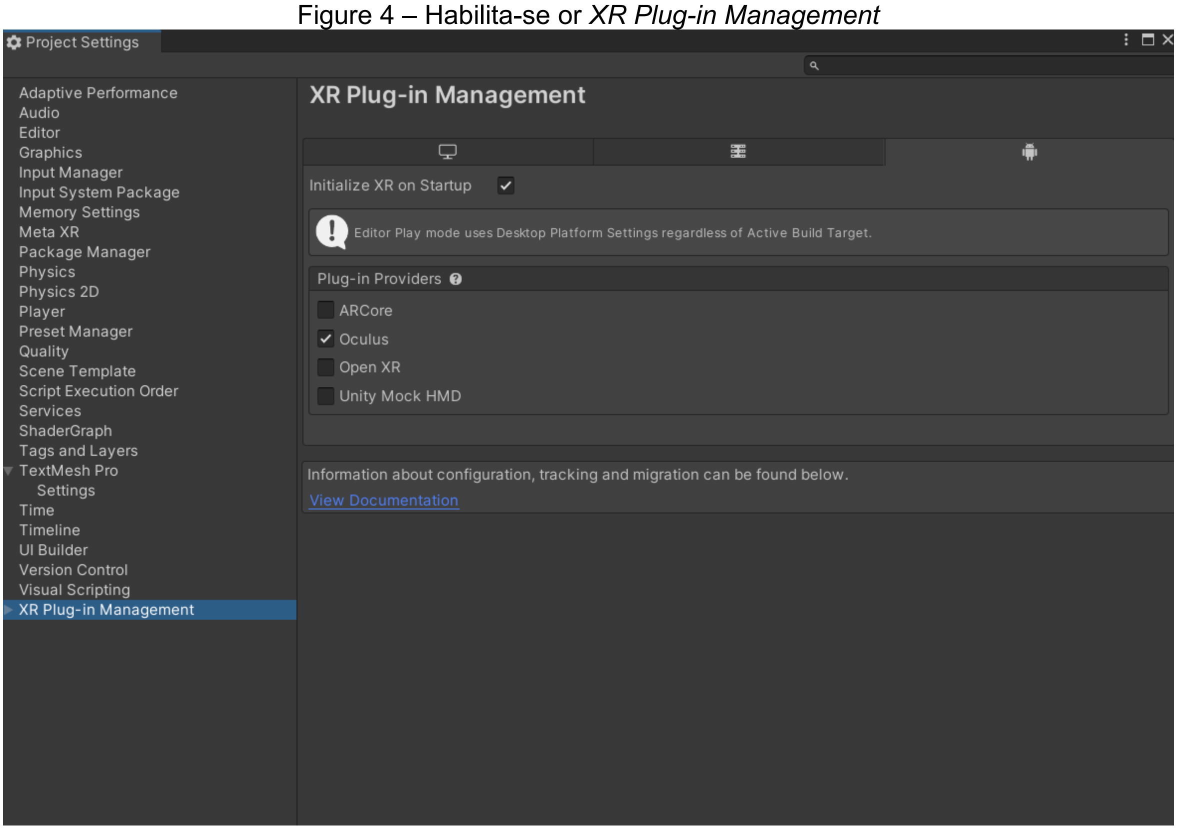
The game or application components have been inserted into an object that stores the information. A *Game Object*[13] is capable of storing the data of a scenario, which can be in the form of a scene object, texture, script or the user's camera configuration. The use of these *Game Objects* is essential for the visual components of the environment to be

[12] Engine that runs a game or software
[13] Object from a game developed in Unity that can store information

developed. These objects are all stored in scenes that together make up the structure of the environment.

Within UNITY, a project was created in version 2022.3.36f1 with the basic Virtual Reality model, which already allows you to test some ready-made assets from this test mold. In order to test the application of the objects in virtual reality, it was first necessary to enable the virtual reality modules within the UNITY creation environment. As shown in figure 4 below, *XR Plug-in Management* was enabled, which allowed the use of virtual reality options for devices such as computers and *Android* systems. This option is present within the edit tab and visible in project settings with plugins for various platforms.

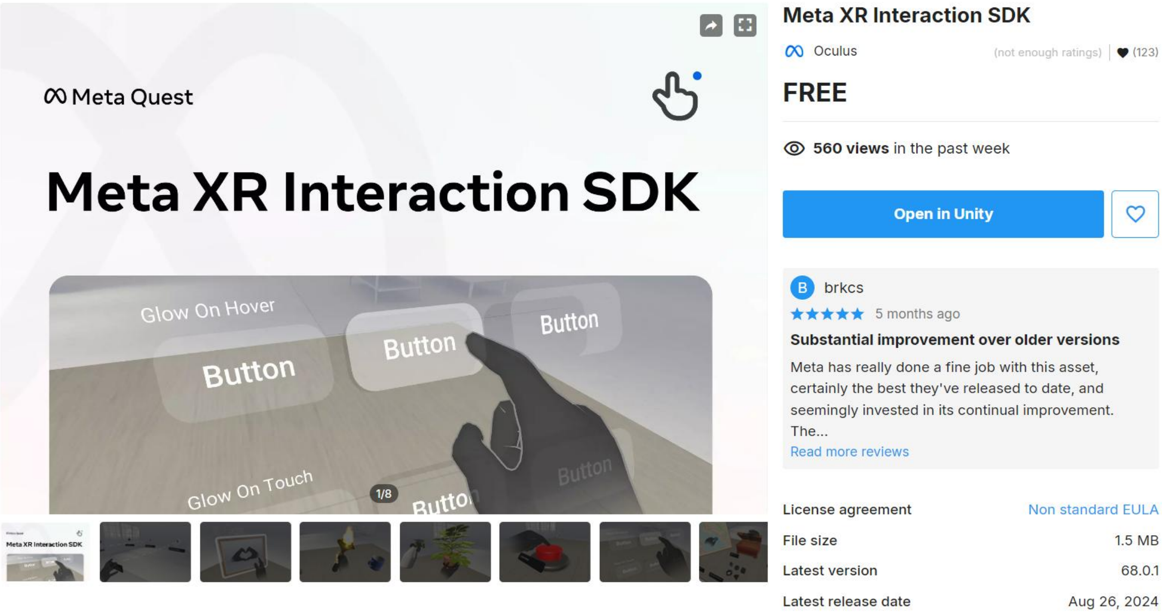
Figure 4 – Habilita-se or *XR Plug-in Management*



Source: (UNITY, 2024)

UNITY also allows you to download packages so that the projects developed can be done more easily, as represented in figure 5. These files called *Unity Packages* can be found both in the virtual store and in the development environment itself, allowing the import into the application. For the project, the *Meta XR Interaction SDK was used,* which allows for greater ease to configure the camera and hands that interact with objects from within the project and install it in its development environment. This package facilitates the development of interaction with objects in virtual reality with the possibility of interacting with components in real size without the need to create [14] new or undeveloped scripts.

Figure 5 - *Meta XR Interaction SDK Download Page*



Source: (Unity Asset Store, 2024)

After that, just insert the desired elements or start the project from a prefabricated environment of items and *scripts*. The kit itself already contains a *driver configuration* with camera positioning that facilitates the movement of the user's head, in addition to containing the same configuration for monitoring the hands that can be used with or without the controls for interaction with objects. Buttons have also been created to improve interaction according to the type of simulation.

For all this to be configured, it is necessary to have the SDK (*Software Development Kit*) and JDK (*Java Development Kit*) packages updated in the versions that are consistent with the hardware that will be used. The first is a collection of tools that develop applications for *Android* and IOS with APIs[15] that allow this development, while the second has tools of the same type, but being a programming kit for JAVA, necessary to compile the codes.

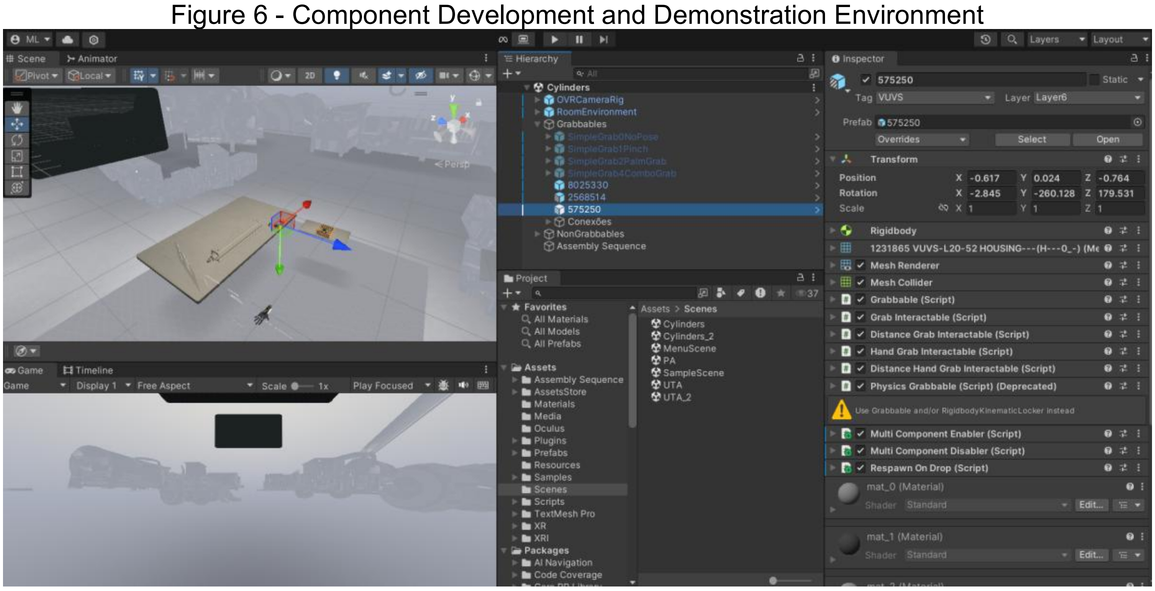
In the second stage, the objects and components were inserted into the project and changed so that it was possible to interact according to the commands of the *scripts*. It should be noted that within this procedure, all the geometries and descriptions of the *Game Objects* will be used so that there is an adaptability for the use of virtual reality in this game developed as a prototype. 3D modeling is extremely important, as it is what will give the user the first impression to the player (DOS SANTOS; CARUSO, 2011).

[14] Sequences of programming codes capable of automating or enabling an action/task
[15] Application Programming Interface

In the project, three free software were used that allowed to improve the adequacy of 3D objects within the virtual reality environment. *Quick Search Plus* allows you to download step *format files of* the components of the industrial automation company FESTO that will be used to simulate the assembly of the assemblies. It was necessary to enter the code of the desired items and open the *CAD* option to access the three-dimensional view of the objects. After that, in the export tab it was possible to select the file format to download. This model was passed on to the *Free Cad software* that made it possible to reintegrate the step document to the gltf *format*, improving its quality in 3D and allowing to perform the last modeling in the *Blender* software, capable of modeling and animating these files and preparing them to be imported into Unity. In addition, the use of the *Meta Quest 2* recorder was considered to develop videos to be placed in the background in order to teach the user how to assemble the sets. With the free editing app *Capcut*, it was possible to edit the videos and insert them into the environment in a way that is concise to visualize the montage. An image of the assembled set made available to the user was also considered.

With the models prepared and imported, it was enough to integrate them into the environment. Each has been changed, within Unity, with "components" of the META SDK that give the visual and physical characteristics, as well as allowing interaction with the user as shown in figure 6. In the image, we have selected the model of the solenoid valve VUVS-L20-M52-MD-G18-F7 with numerical code 575250 with collision components, hand interaction and user control, 3D physics and *scripts* to enable and disable the same elements assigned to the object.

Figure 6 - Component Development and Demonstration Environment



Source: (Unity, 2024)

For the last stage, the project will be suitable for the hardware and devices that perform the simulation in virtual reality. This process will be done after the implementation of the tests, and can be repeated several times as the software progresses and develops for the project. When finishing the insertion of the objects and *programmed scripts* , it was necessary to import the software to the desired device, creating a *build*[16] and implementing it in the hardware according to the specification. To do this, *Gradle*[17] was used to create and manage the projects according to the SDK and JDK settings. As it is a build and dependency management tool, the files were generated when building the projects for the chosen platform.

All the time, new applications arise, due to the demand and creative capacity of people through VR, the human-machine interaction has changed (RODRIGUES; PORTO, 2013). As technology advances, virtual reality has been fitted into a greater number of platforms, from cell phones to own devices.

The Meta Quest 2 *device will be used in the project*, being the latest virtual reality headset that has dominated the virtual reality device market since 2022. According to Raymer *et al* (2023), the device contains a Qualcomm Snapdragon XR2 processor and an LCD panel with a per-eye resolution of 1832 x 1920, with a frame refresh rate of 120Hz, along with an operating system based on *Android* 10, with 128 or 256 GB of internal memory.

For modeling the environment in 3D, the *Meta Quest 2* will be a very useful device due to its ease in designing the software's frames in real time, with a very large realistic advance. The device will be a major key in advancing the project, enabling users who will be able to test the equipment with the integrated environment to have an immersive and deep experience of equipment maintenance and assembly assemblies. In order for us to use the device, it is necessary to activate the developer mode in the *Meta Quest* application, present in the menu and in the devices option, finding the device located and enabling this option.

For the implementation on the device, it is necessary to go to the *File* tab and select the *Build Project option*. After that, the Android option must be selected and change the platform to the chosen one. Within this option, it was essential to choose the scenes that will make up the environment so that they were all imported into the virtual reality glasses. All this configuration can be seen in figure 7. With the adjustments, the *Meta Quest 2 will be connected* to the computer from a USB cable and thus generate the *build* for the device.

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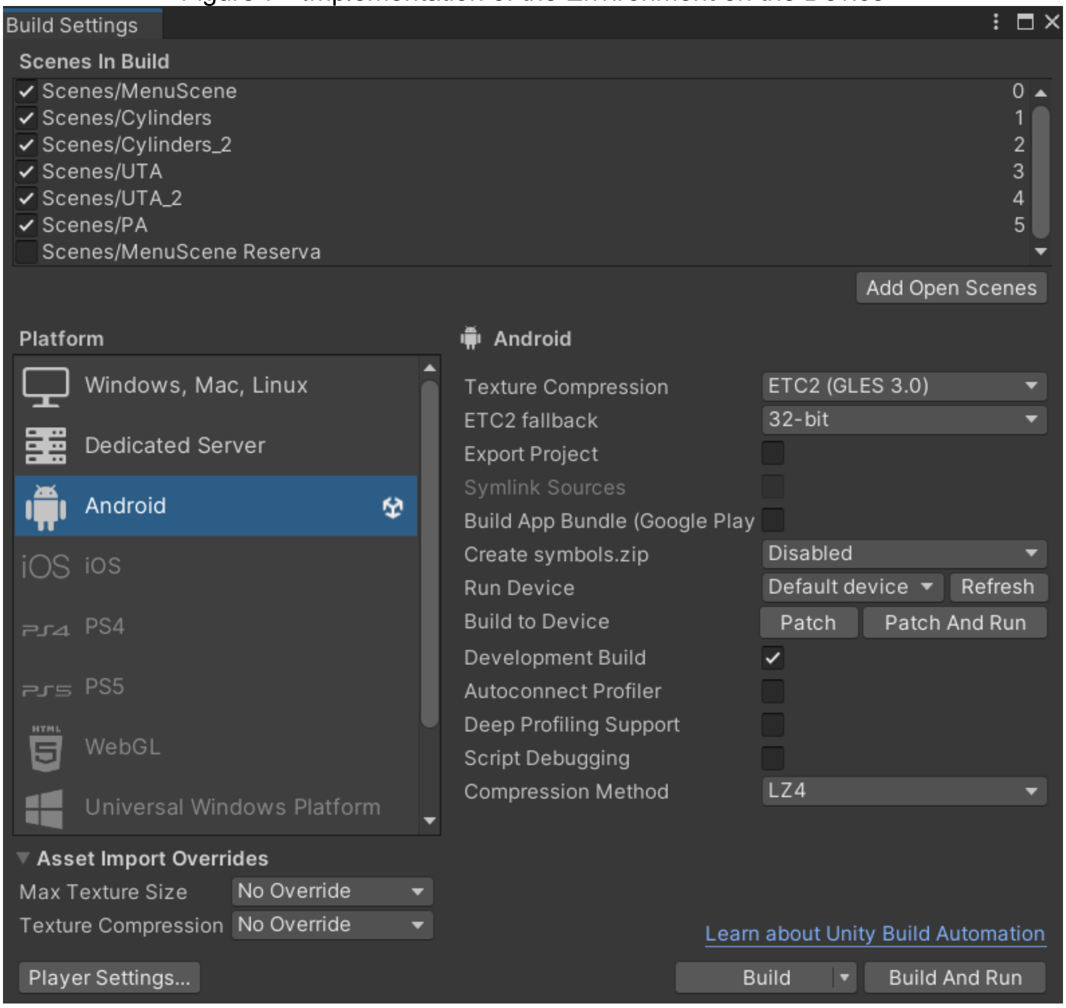
[16] Converting the project into software
[17] Tool used for project conversion

After charging, it was possible to view the environment inside the device, enabling various interactions with objects.

Figure 7 - Implementation of the Environment on the Device

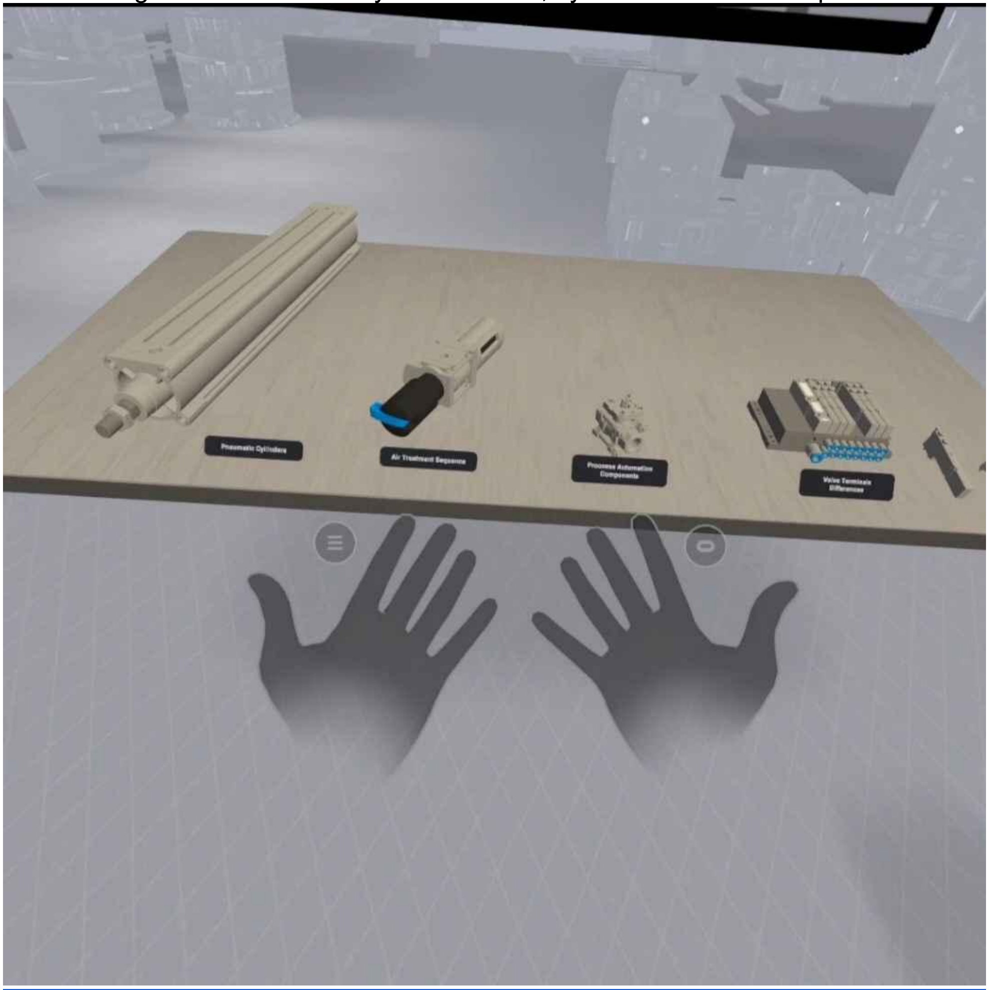


Source: (Unity, 2024)

RESULTS AND DISCUSSION

With the integration of the software created by UNITY, it was possible to implement the environment on the *Meta Quest 2 device*. The environment was configured to integrate virtual reality, along with scene objects in the background, which allows for a greater depth of an industrial scenario. Figure 8 has a *link* that leads to a video demonstrating the virtual reality environment developed according to the methodology of this article. You can access it by hovering over the image.

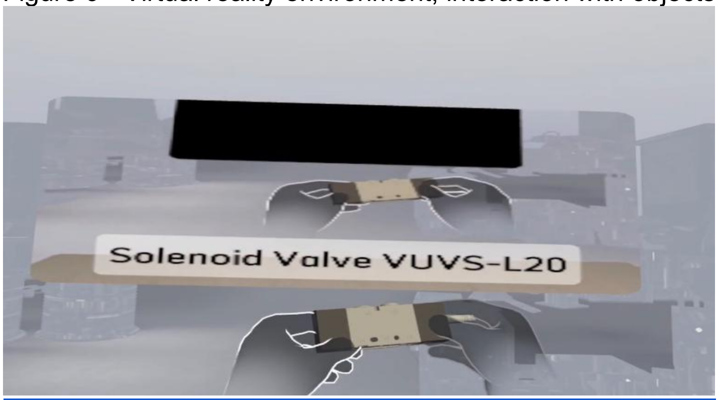
Figure 8 - Virtual reality environment, cylinder accessories option



Source: (Author, 2024)

It was verified that there were no problems in simulating the objects in the environment, keeping the scale at real size and allowing the user to easily interact with the objects in the scene. In figure 9 there is an example of how the user uses the explanatory video so that he can manipulate the scene objects, making it possible to perform the assemblies according to the instructions. In this image there is a *link* to a demonstration of the process of assembling a pneumatic cylinder with its accessories.

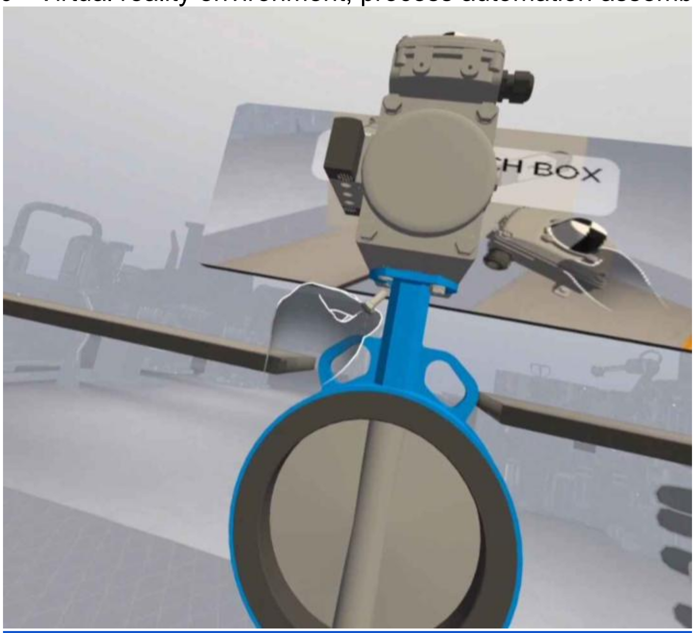
Figure 9 - Virtual reality environment, interaction with objects



Source: (Author, 2024)

With the interaction of objects, it was possible to make the assemblies according to the tutorial videos in the background with neutral and self-explanatory language. In figure 10 it is possible to see the assembly process of a rotary actuator in a butterfly valve, and this assembly is commonly used in process automation systems. A demonstration was inserted in the image through a *link* as in the other previous examples.

Figure 10 - Virtual reality environment, process automation assembly option



Source: (Author, 2024)

Through the developed model, it was possible to develop more scenes to apply different types of assembly solutions, only differentiating in the aspect of the assembly and in the way the steps are made to join the objects.

FINAL CONSIDERATIONS

It is possible to simulate an integrated environment in virtual reality capable of teaching the user how to assemble industrial automation sets and instruct them to use these learnings in their routine or for their own knowledge.

The model created allows the operator to interact with objects with physical properties and real sizes through touch, enabling him in the technical knowledge to develop assemblies and group objects according to the instructions given by the software. Therefore, it is possible to conclude that virtual reality is a great technology capable of integrating the user into the industrial environment through 3D simulations.

Some limitations still occur due to the UNITY platform because it is not a software totally focused on the use of virtual reality, which can create some problems and errors depending on the development that can be exhausting for the user and the developer.

Future updates may include a continuous improvement in the development of the application, allowing better user interaction with the system and increasingly integrating with the recurrent evolution of Industry 4.0 with the use of more technologies in order to enable the human being in the industrial environment.

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