VIRTUAL REALITY TRAINING SYSTEM FOR INJECTION MOULDING OPERATORS

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Abstract: *This paper presents a virtual reality training system intended to be used by operators in injection moulding manufacturing. This case study has been focused on the assembly process of a head brush injection mould. The Assembly process of injection moulding represents a complex task due to the complexity and number of components involved in the final assembly. The injection mould has been designed in SolidWorks and exported in Blender to facilitate the VR integration of the 3D models. The virtual reality application has been developed using Unity and SteamVR plugin. This application allows the operator to easily understand the steps required to assemble an injection mould and it can be extended to be used on a larger variety of different types of injection moulds. The case study proposed virtual reality system has been tested on a desktop PC paired to Valve Index head mounted system and includes the following four different training areas: injection mould, parts assembly, 2D drawings analysing and video tutorials. Each training areas has been created to provide specific training related to the complex process of injection moulding.*
Key words: *virtual reality, training system, injection moulding, computer-aided design, assembly analysis.*

1. INTRODUCTION

During the last years, large numbers of industrial companies have decided to integrate different types of VR Systems to reduce the required time and increase the safety factor of different types of jobs. This is mainly because, nowadays, almost every company that produces VR Systems that can provide the user with a very immersive experience. Since the beginning of VR Technology, various domains have been the major direction for development like training, education, and entertainment. To create an experience as close to real-life for the operator, the VR Headset must be able to transmit a vast array of signals to the operator, such as sight and hearing. Even though the process of importing CAD models into VR, which may lower the probability for an industrial business to implement this technology, it is possible to import them using tertiary software, like Blender or Autodesk 3ds

Max, without having all the properties set in the design stage [1].

In the early stages of the development of VR technology, the equipment needed to run a program was very bulky and very expensive. As the overall development of the electronic and computer domain has evolved, the VR system has evolved and became much smaller and cheaper, so that anyone who wanted to experience this type of technology could buy themselves a VR Headset system [2].

The evolution of the VR HMD is presented in Figure 1. starting from the initial prototypes designed by various VR pioneers, up to complex CAVE systems with multiple screen and modern lightweight HMDs with haptic capabilities [3],[4].

Well-known technology companies such as Google and Samsung have started to design augmented reality hardware intended for mobile devices such as smartphones. The most affordable system was the Google Cardboard and soon after a wide variety of plastic

smartphone holders have appeared on the market.

One of the most important technological milestones in Virtual Reality domain was the prototype developed by Palmer Luckey.

After the release of Oculus Rift DK1, Virtual Reality has become accessible to a wider audience, making it easier for developers to create and publish VR Applications.
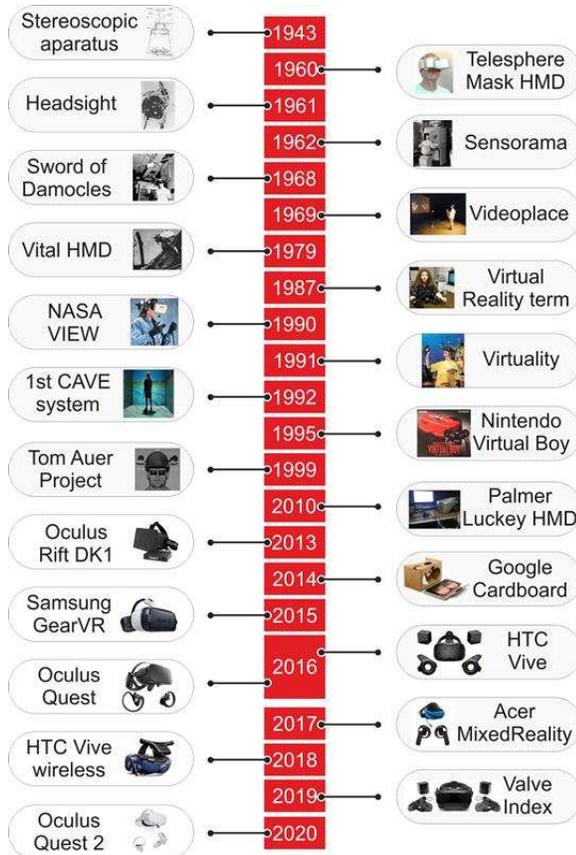

Fig. 1. VR HMD Evolution

2. STATE OF ART VIRTUAL REALITY TRAINING SYSTEM

Nowadays, VR technology is used in a large variety of domains. Some of the domains are the following: Robot Training, Medical, Industrial Assembly and even Fire Training [5].

As presented within the introduction both Virtual Reality and Augmented Reality are not new, but recent advances in computational power, camera sensors and high-resolution portable displays have overcome the constraints that have limited the widespread adoption of these technologies in various sectors and domains.

At Kuka, one of the world's leading suppliers of intelligent automation solutions like industrial robots, Virtual Reality technology is used for the training of the operators. In their developed VR program, the operator is able to manoeuvre the industrial robot in a safer environment [6].

In the medical domain, Virtual Reality is used to either teach a medical student how to perform different types of medical intervention or to teach doctors new types of procedures. In either case, training is done in a safer environment without having to do the procedure on a human being. Particularly, this type of technology is used in neurosurgical training, allowing neurosurgeons to perform complex surgical procedures. This type of technology is also imperative in the development stage of surgical residents skills [7].

Virtual Reality can also be used in the industrial domain [8], specifically the assembly steps of a process. The VR environment enables the rapid configuration of the industrial workplace and allows the operator to test different types of manual operations. This allows the company to test their factory configuration, having the possibility to check if any bottlenecks appear in the process, and modify it until they reach a configuration that satisfies their needs. At last, the possibility of training one of their new operators in a safer environment without reducing the productivity due to the redeployment of workers to help the new employee [9],[10].

Virtual Training Environments (VTE) can also be used in the Fire Fighting Department. From, to create an almost real-life simulation to train firefighters on how to put out different types of fires, a tracker can be placed on the fire extinguisher and its model can be imported in the Virtual Training Environments. This way, whatever move the firefighter does with the fire extinguisher in real life, the same movement will appear in the simulation. Thanks to this, the firefighter can control very precisely which way the fire virtual fire extinguisher will shoot its foam to extinguish the fire [11]. Thanks to this type of VR application, the firefighter can learn

how to react in a wide variety of scenarios without facing the danger of doing something wrong in the real-life.
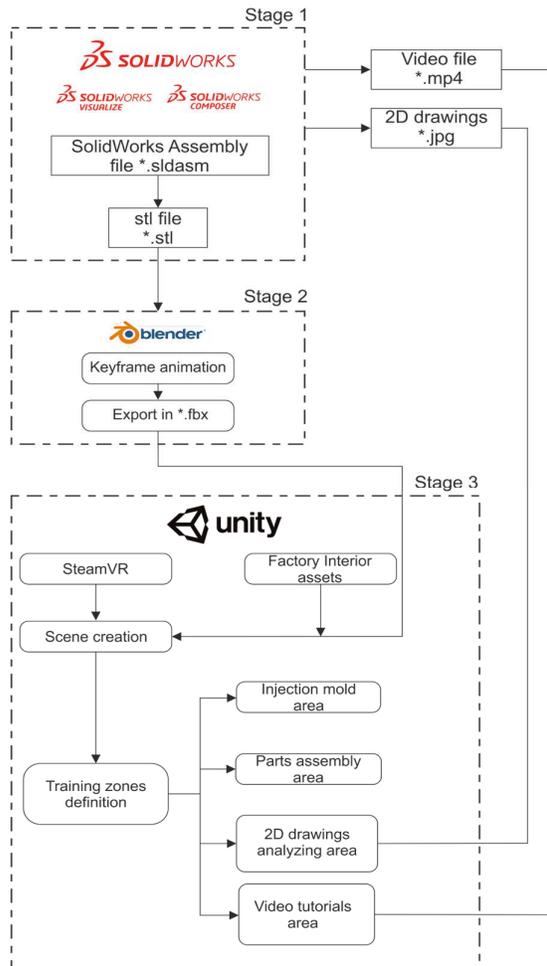
3. VIRTUAL REALITY TRAINING SYSTEM

Fig. 2. Development stages

3.1 The injection mould design

To create an application that will provide the operator with a more friendly and safer environment, we first had to decide which type of assembly would our simulation be focused on. After a long time of consideration, we decided to go with an injection mould specifically made for the injection process of a head brush. The injection mould has been done using SolidWorks 2020. Also, the head brush flow simulation has been done in SolidWorks Plastics and the two tutorial videos found in the "Video Area" of the VR application have been

done using SolidWorks Composer and SolidWorks Visualize. The final output from SolidWorks were the 3D model as a *.stl file format and the 2 videos.
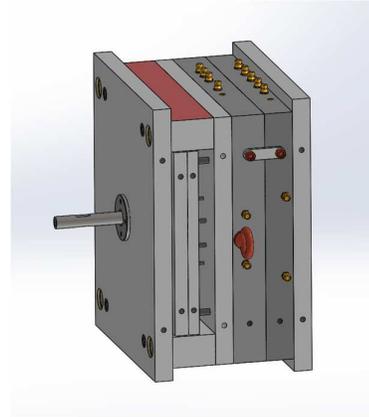

Fig. 3. Injection mould assembly within SolidWorks

3.2 3D Model and the exploded simulation

To make sure that the 3D model created in SolidWorks can be properly imported into the Unity Project, we had to use a tertiary software. The selected software Blender since the process of learning this program was short and easy. The *.stl file has been imported into Blender and saved as a. blend file. After that, we decided that the best way to do a simulation that will show the assembled and the exploded model was to create a keyframe animation which will be saved in the *.blend file. When the *.blend file will be imported into Unity, both the 3D model and the keyframe animation will be imported into it and can be further used to create different types of actions.
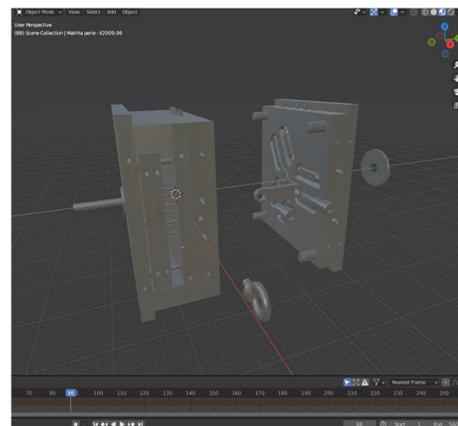

Fig. 4. Blender scene view

3.3 Unity Application

To start the development of a VR Application, one of the major steps required is the selection of the VR Head Mounted Display (HMD). In our case, the selected HMD was Valve Index. To create a better compatibility between the application and the HMD, the choice of the main asset, specifically made to develop VR Applications, was very important. Due to this, we decided that the best VR development kit was SteamVR.

Developed by Valve Corporation, SteamVR is a free package specifically made to work with VR Headsets built by HTC. Thanks to the usage of this package, all the primary functions are already created and the required configuration between the application and the headset is already done. Thanks to the compatibility between the package and the HMD, to test the application, the simple use of "Plug & Play" is enough.
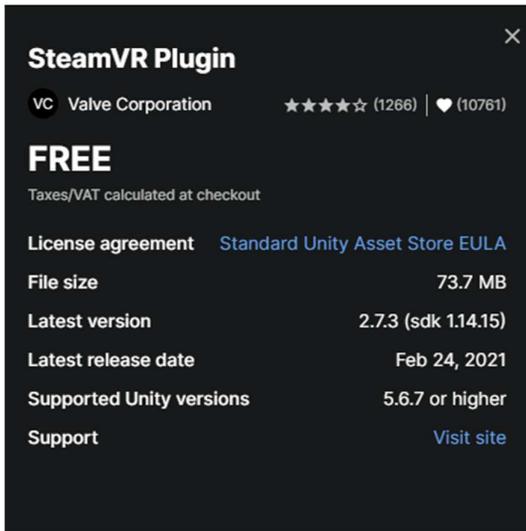
Fig. 5. SteamVR Plugin Asset

To facilitate the creation of an "as close to reality" environment in which the operator would feel very familiar, we decided to search for a suitable package on AssetStore that would provide this feeling. We decided that the best asset for our desired finished application would be a factory one, and we went with the "Factory Interior" developed by wArtStudios3d. This package provided us with a real-size factory with different types of equipment to work with.

Even though the factory looked very realistic, we had to delete some of the equipment to create the needed space for all the required areas: Injection Mould Area, Part Assembly Area, 2D Drawings Area and Video Tutorials.

Fig. 6. Factory Layout with all the created zones

Due to the injection mould assembly not retaining its selected materials when transforming the piece from a *.sldsam file to a *.stl file using SolidWorks and then transforming it again from *.stl file to *.fbx file using Blender in order to import it in Unity, we decided to directly modify the material of each part in the VR application, in Unity. In order to do so, the creation of different types of materials was necessary. We first created the basic metal material, and, from it, we decided to create other materials, having the same metal texture but painted in different colours to facilitate the recognition of each part. For example, the red metal material has been used for the safety parts, the blue metal material for the outer plates, the gold metal material for the would-be copper parts and the basic grey metal material for all the rest of the parts.

Fig. 7. Injection mould with materials visualisation

Three buttons were created using the example button from the SteamVR sample scene to provide the operator with a way to see the injection mould in the "exploded" state, assemble the mould and show the names of each part.

The first button, called "Assemble", allows the operator to show the specific animation, using the Animator function found in Unity. The "Assemble" animation is the same as the "Explode" animation, the only difference is that it is played in reverse. The second button, called "Explode", allows the operator to show the animation just as how it has been already created in Blender. The third button, called" Toggle Labels", allows the operator to show the name of each part found in the injection mould assembly when the assembly is in the "exploded" state. Thanks to this, the operator can easily learn to name and position of each part.
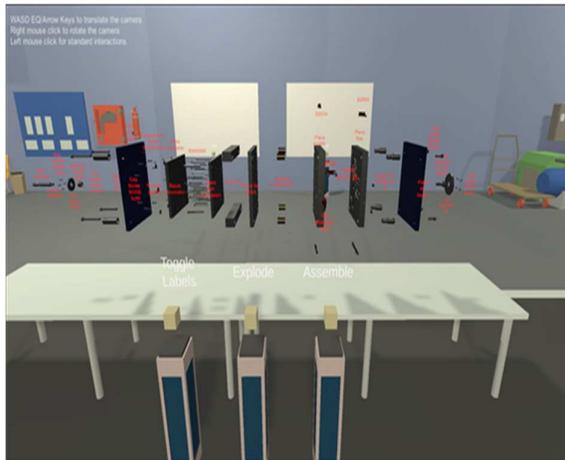
Fig. 8. Injection Mould Area

A specific zone for the preview area has been created using large tables placed in a "U" shape. The height of the table has been specifically tweaked so that the player can easily interact with the objects placed on the tables. Each part from the injection mould assembly has been placed on the tables to help the players better identify them. For all the parts, the specific material found in the large injection mould has been also assigned to them. To better help the player identify each part, a set of labels has been created with the name of each part.

Fig. 9. Parts Assembly Area

To make the application more realistic, the operator can interact with each part, grab them and analyse them. To do so, each part component would have to have the following elements: "Mesh Collider", "Rigidbody", "Interactable", "Throwable", "Velocity Estimator" and "Steam VR_Skeleton_Poser". For each part found in the assembly, using the "Steam VR_Skeleton_Poser" a specific grabbing pose has been assigned allowing the user to grab the object more realistic, just as they would grab them in real-life.

The result of the injection process, the head brush, can also be manipulated within the virtual environment, allowing the operator to better analyse the finished product.

Fig. 10. Different grabbing poses

A special area has been created where the operator can watch the tutorial videos made using SolidWorks Composer and SolidWorks Visualize. To use the tutorial videos in Unity,

the video format had to be .mp4. For each video, a quad object had to be created, having the "Video Player" function and, in this function, the desired video had to be selected. After selecting different characteristics for each video like the speed of the playback, whether the video should play in a loop or not or whether the video should start from the first frame or not, all that remains to be done to make the videos playable by the operator was to select the type of trigger that will start or stop the video. To make the application easier to understand, we decided to repurpose the buttons found in the injection mould area, the only difference being the "On Button Down (Hand)" expression. In this case, this expression refers to the video that is supposed to start or stop with the function "VideoPlayer.Play".
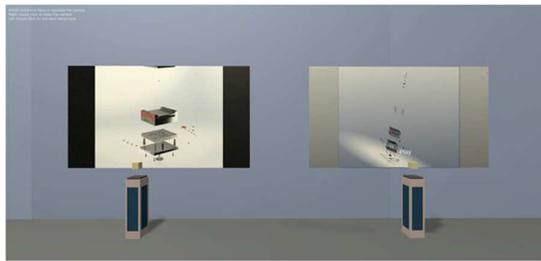

Fig. 11. Video Tutorial Area

A specific area where the operator could analyse the 2D drawings had to be implemented in the application. To do so, we required the following two major things:

- The first one was the panel on which the 2D drawings would be placed. We decided that it would be best to create our panels and not search for some similar assets on the asset store since we could create a universal dimension for the panel on which different 2D drawings having different formats could be placed. To create the panel, some objects from the "Factory Interiors" assets have been repurposed.
- The second major thing was to create the 2D drawings. To do so, the selected software was SolidWorks. Using this program, we could create all the 2D drawings for each part, excluding standardized parts which are going the

be bought from the supplier, and save them as .pdf. Since Unity does not support having .pdf files in its applications, we had to transform them into .jpg.

The panels were placed in a similar way in which the tables from the "Injection Mould Area" were placed, in a "U" shape to facilitate the movement between the panels. Also, on each panel, in order to make the drawing the correct dimensions and not having the operator get very close to them to understand the details, a number of two small-format 2D drawings or only one large-format 2D drawing could be placed on each panel.
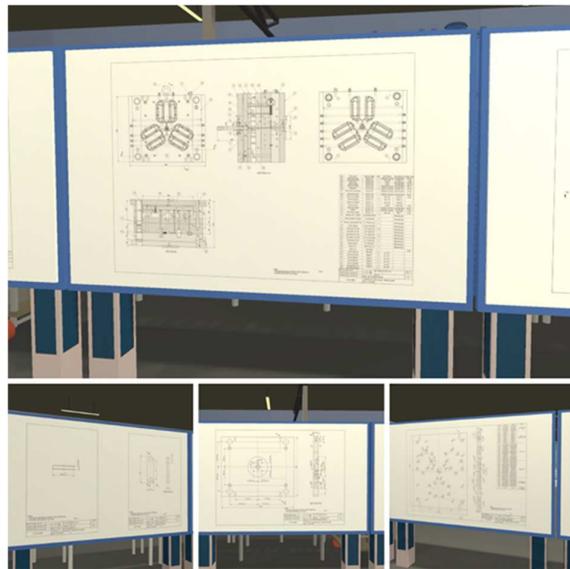
Fig. 12. Drawing Analysing Area

4. CONCLUSIONS

The proposed VR development workflow can be used to deploy virtual reality immersive applications with ease. The three different training areas enable users to follow multiple training scenarios each, focused on specific elements related to injection mould design and assembly.

The virtual reality application allows users to manipulate heavy components such as support plates, ejector box, mould core and mould cavity. Other components such as ejector pins,

runner, sprue, core pins and ejector system cover are also available within the assembly training areas. A special attention has been given to the hand posing in relation to each component within the virtual reality environment to enable realistic grabbing.

From the initial experiments carried out with the current developed application, it was concluded that the VR proposed application allows the users to be familiarized with the injection moulding process and the assembly of injection mouldings. The initial users of the application have been students of the Technical University of Cluj-Napoca, some that have had previous knowledge regarding injection moulding design and assembly. The user had no difficulties manipulating the Valve Index controllers allowing them to explore the virtual reality environment and its four training zones.

The authors intend to integrate multiple mould design and training areas as future work within the designed virtual reality training system. Currently, the application has been created for Valve Index HMD which requires a Windows operating computer to be paired with the headset, the authors intend to compile the application to be compatible with Android-based HMD such as Oculus Quest 2 which is a more accessible and lightweight virtual reality headsets.

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Sistem de instruire în realitate virtuală pentru operatorii echipamentelor de injecție mase plastice

Rezumat: Această lucrare prezintă un sistem de instruire în realitate virtuală destinat să fie utilizat de operatorii din producția pieselor din mase plastice realizate prin injecție. Acest studiu de caz s-a concentrat pe procesul de asamblare a unei matrițe aferente unei perii din plastic. Procesul de asamblare a unei matrițe reprezintă o sarcină dificilă datorită complexității și numărului mare de componente implicate în asamblarea finală. Matrița utilizată în procese de injecție mase plastice a fost proiectată în SolidWorks și exportată în Blender pentru a facilita integrarea VR a modelelor 3D. Aplicația de realitate virtuală a fost dezvoltată folosind pluginul Unity și SteamVR. Această aplicație permite operatorului să înțeleagă cu ușurință pașii necesari pentru asamblarea unei matrițe și poate fi extinsă pentru a fi utilizată pe o varietate mai mare de tipuri diferite de matrițe de injecție. Sistemul de realitate virtuală propus de studiul de caz a fost testat pe un computer desktop și un sistem Valve Index de realitate virtuală, acesta include următoarele patru zone de antrenament: procesul de injecție, asamblarea pieselor, analiza desenlor 2D și tutoriale video. Fiecare zonă de instruire a fost creată pentru a oferi instruire specifică legată de procesul complex aferent injecției maselor plastice.

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