Monitoring console using Virtual Reality for automotive industry

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Abstract. One of the technologies used in Industry 4.0 is virtual reality and augmented reality in the industrial applications. These technologies allow: the introduction of the operator in the production process with minimal risk, in the training process (learn manufacturing), the realization of maintenance works with a much more detailed vision of the equipment and the process, the realization of consoles to monitor the manufacturing process and equipment with extended facilities compared to any type of console that has been used before. In this paper we will present an example of a monitoring console using virtual reality. As we will show, the virtual environment accessible through the virtual reality headset can be used as a console with an extended viewing angle in which indicators on the status of the monitored process can be displayed. The indicated values come from IoT equipment with current sensors and temperature sensors. Also, by navigating, using teleport tool, in the virtual environment you can get an overview from several angles of the monitored equipment (in our case a chassis welding workstation) with minimal risk. The environment contains both a modeled image (a 3D sketch of the equipment) and real images of the equipment captured through industrial cameras placed next to the real equipment. In the virtual environment the two "live" video streams are displayed as 2D screens. With this modern monitoring tool, the work standards will be developed that the operator can use in training and in the work process. The system presented in the paper is implemented with an Oculus Rift kit with headset and touch consoles for capturing the movements of operators and their contacts with virtual objects. The virtual environment is fully implemented using Unity. The system will model workstation for chassis welding. Two IoT devices will be used: one with temperature sensor and the other with current sensor. Two industrial video cameras with high resolution will also be used to capture images from the workstation. As a result, along with the presentation of the functional system will be presented a model of operational standard made by captures from Unity when exploring the virtual environment.

1. Introduction
One of the most modern tools and environments for displaying information is virtual reality and extended reality (augmented reality, virtuality). It has multiple fields of applicability: entertainment, education, sports, medicine but also in industry. One of the components of Industry 4.0 is the use of virtual reality, extended reality and virtuality [1] in production processes.
On the one hand, virtual reality can be used in lean manufacturing. Virtual courses have been built through which production lines can be explored and virtual manufacturing processes can be visualized [2]. Through Touch devices the learner can interact with virtual objects. The use of virtual reality in lean manufacturing is a field still in research but there are also commercial solutions that can be applied for specific manufacturing processes. The difference between a training on a "classic" 2D environment and one done with virtual reality is related to the great interactivity we find in the virtual reality environment, the increased amount of information we get by navigating virtual reality and the proximity of real operating scenarios. This is also the reason why this type of training will certainly be the main educational method of the future.

On the other hand, virtual reality and augmented reality are also used in maintenance work on industrial equipment [3] or in training for maintenance work [4]. Augmented reality allows the operator to be guided by the functional diagram of the machine superimposed over the real image that the operator sees. Also, through virtual reality the operator can see the consequences of his actions on the machine before they are applied. Such maintenance tools are studied in very recent research and attempts are being made to implement them in commercial solutions.

Last but not least, virtual reality can also be used as a method of monitoring and exploration in the production process in design [5] or remote control [6]. The operator can monitor the production process with detailed images of the schematics of the components involved that can be present, in a virtual way, inside the process. All this would be impossible in real environment, so virtual reality extends the monitoring capacity to the operator.

The paper features a virtual reality-based monitoring interface that can be used for both training and equipment monitoring. The interface will have the following features:

- It will implement a virtual environment in which the equipment is modeled (chassis welding installation);
- It will allow interaction with the equipment via Touch input devices. It is allowed to hold the tools or parts "by hand" and place them in another location;
- It will allow the monitoring of real data coming from two IoT devices that measure temperature and current consumption. The connection to the equipment is made by implementing some "driver" functions.
- Allows to monitor two images from two industrial cameras. Thus in the virtual environment we can have "real" images of the working station.
- It will allow the operator to move in the virtual environment through the options of physical movement (by movement) and by teleportation.

Some of the features listed above are specific to virtual reality systems: modeling equipment, interaction and manipulation of virtual objects, moving in the virtual environment. Another part are specific, innovative elements that have been brought and that will be presented in this paper: taking real data from IoT devices and "bringing" them into the virtual environment where they can be viewed, viewing virtual images in the virtual environment, modeling of specific chassis welding equipment in the virtual environment. The structure of this article is as follows: the next section is dedicated to the presentation of the system, section 3 will present the virtual environment as it was built and section 4 will present how to test this interface. The paper ends with conclusions and future directions of development.

2. Presentation of the interface
Along with the virtual reality kit - the Oculus headset and Touch controllers - which is the main component of the monitoring interface, there are the following components - as shown in figure 1.
The two IoT devices for the acquisition of "real" data on the spot via temperature sensors and power consumption are based on the Wasp mote 1.2 board from Libelium. The board contains an ATMEGA 320 microcontroller, an interface to which the sensor (temperature or current pliers’ sensor) is connected and a shield together with the XBee transceiver - which communicates in the 2.4GHz free band at distances of about 1 km.

Both devices acquire data from sensors, package it, and transmit it over the XBee wireless LAN to the server. The network is a scalable one, it allows the connection of several IoT devices.

Another component consists of the two industrial chambers. The virtual reality kit also has a headset camera that allows the overlapping of real images with virtual ones (augmented reality). In this case, it is desired to acquire images from the industrial process from two different positions. This is why two industrial chambers were used. These are IP cameras wired to the network where the PC server station is located. The cameras are 720p HD and allow monitoring in daylight conditions but also in low IR lighting conditions. This allows them to transmit images from the welding process when the machine is operated or when it is switched off.

The PC server station is the one that runs both the virtual environment displayed on the virtual reality kit and the interface for acquiring data from the sensors and the part for acquiring video streams from the cameras and providing it to the real environment.

For the virtual environment was used Unity 2018.4.20 as design environment. It will also be used for running application. The gateway is the device connected to the PC (via USB) through which data is taken from the XBee wireless network. A NodeJS server is used to retrieve data from USB from the

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**Figure 1.** Monitoring interface – block diagram.
gateway and transmit it as a web service to Unity. Finally, the video streams, in RTSP format, reach the PC via the intranet and are then taken over by two VLC instances and transformed into HTTP streams. The latter can be integrated into Unity - just like a movie that is provided on YouTube and has its own address.

3. Presentation of the virtual environment
The virtual environment was made entirely in Unity. Several stages were completed of its realization.

3.1. Equipment modeling
First of all, the equipment used was modeled. Its modeling was done by using 3D primitives: cubes, parallelepipeds, cylinders and spheres as well as by applying textures - free textbooks from the internet were used for textures. Also, in the model of the electric motor that drives the arm of the welding station and for the robot arm itself, a free model from the internet was used. The models used in the virtual environment are illustrated in figure 2.

![Figure 2. Models for the virtual environment.](image)

3.2. Implementation of actions to catch virtual objects and manipulate them
To take inputs from Touch controllers, "driver" interfaces have been built in Unity. Such an interface handles events from a Touch controller. Specifically, when a controller is moved or pressed it converts the value returned from the controller sensors to real numbers. These real numbers are called FloatActions and are associated with "hand" objects. In this way, by moving a controller or by operating it, the effects will be seen on the hand model.

The construction of the drivers' scripts is done in code (C#) and the association with hand is done in the Unity graphical interface.

The contact between the hand object and a virtual object and the implementation of more complex actions of grabbing the virtual objects and even throwing them is done by introducing objects already made for this purpose (prefabs) and associating them with virtual objects. The properties of these prefabricated objects allow actions of grabbing and moving virtual objects by associating the vector transform.rotation and transform.position from the hand object and the grabbed object. To generate a speed when throwing objects, a script (built) with hand objects will be assigned. The steps taken to implement the action of catching and manipulating virtual objects are shown in figure 3.
3.3. The movement in virtual environment

There are two forms in which the movement has been implemented in the virtual environment: physical movement - as in the real environment and movement by teleportation.

Physical movement occurs by default when the virtual camera is associated with the head set. The movements of the head are taken over and converted into movements of the main camera in the virtual environment because the headset has accelerometers on all three axes. In the same way, the movements of the person holding the headset are taken over and converted into movements in a virtual environment on the same scale. So, moving in the real environment, we also move in the virtual environment. However, physical movement has some drawbacks. First of all, it is limited due to the cables through which the headset is connected to the PC. Secondly, it is not safe: the person can hit objects that exist in the perimeter where the movement takes place. This is also the reason why a second form of travel was chosen, namely by teleportation.

Unity has the tools to easily implement teleportation. An object of the Teleporter Instant type can be associated with one of the Touch controllers (in our case the one on the left hand). A cursor is also associated with the same controller. By operating the joystick, a cursor is displayed that indicates the place where the movement will be made and by releasing the joystick, the “teleportation” takes place in that place. This method of movement allows you to travel in the virtual environment over long distances.

Figure 5 shows how the teleporter is associated in Unity.
The aspects presented so far are typical for a VR application. The following elements are specific to the type of application we have developed and presented in this paper.

3.4. Display data from IoT devices
In Unity, it is allowed to connect to the USB ports of the PC in order to retrieve the data that a device transmits there. Specifically, communication is implemented at the level of a C# script that can generate actions which are then interpreted at the Unity level. A general organization chart (without going into the details of the implementation) is presented in figure 6.
3.5. Display video streams
Images taken from on-site industrial cameras were captured by video mini-servers using VLC. Its role is to turn the video stream from RTSP format - incompatible with the Unity environment into HTTP stream - the same type of stream that is used for Youtube movies. So, there will be two VLC instances that will run for the two video streams. For using this solution with a larger number of cameras, it can be purchased a professional Video Management System (VMS) application.

The integration of images is done in the same way as data from IoT devices: canvases of the same type have been created but here links to video streams have been associated. In this way, you can see real images on the spot in the virtual environment.

Canvases are objects that will not be affected by the physical laws of the virtual environment: they can be placed anywhere, including can float in the air - so did the two indicators from IoT devices. Thus, the monitoring panel made in the virtual environment can be placed in positions impossible to reach in reality with maximum ergonomic comfort for the operator.

4. Testing the monitoring interface
Figure 7 shows the final shape that was given to the interface - of course this shape can be adjusted at any time to be able to adapt to another type of process.

![Figure 7. The final interface before running.](image)

The scenario here is as follows:

The operator is placed next to the conveyor belt on which are provided the parts to be welded by the robot. It must ensure the correct placement of the parts to be welded. In this phase, the pieces are red and blue cubes. The blue cubes must be placed on the blue support and the red cubes on the red support. The movement of the operator to place the cubes on the two supports is a physical one. The operational scenario is a simple one, the pieces appear randomly - simulating the production flow.

To the left of the operator is the robot - inoperative until the part is placed correctly (on the correct support). To the right of the operator is the belt drive motor - its movement is limited by these machines - as is the real case.

At the level of the two supports on which the parts are placed, there are real video streams. By placing the part, the operator can observe the real support and can monitor the real welding process. In
front of the conveyor belt there are indicators on the temperature at the working point and the current consumption of the equipment.

In figure 8 we attached several images during the operation.

![Figure 8. Operating in virtual environment.](image)

As you can see, the operator handles virtual objects safely - so the platform can be used for a training scenario. Placing the equipment, using as realistic models as possible makes the operator get ready for the activity he will perform, but it can also be a very useful support for analyzing the ergonomics of the work point.

On the other hand, as you can see, we are talking about a very interactive monitoring platform. As you can see, we have real data on the spot: measured values or even images. In this way, the platform
can be used for maintenance operations: monitoring the status, performing virtual actions that can then be actually reproduced with the visualization of the results. Also, the actions that take place in the real environment (e.g., the automated welding process) can be monitored in detail and transposed into the virtual environment.

5. Conclusions
As we have seen, the use of virtual reality greatly expands the possibilities of training, analysis of workplace ergonomics, monitoring for maintenance or production flow operation. The paper presents typical features of VR applications: integration of 3D models for equipment (as accurate as possible), capturing operator movements, actions on virtual objects, moving in the virtual environment, combined with own monitoring solutions: acquisition of real data from IoT devices and displaying them in the virtual environment, purchasing video streams and displaying them in the virtual environment. All these features "collected" in a VR monitoring platform are used in the industrial environment. The scenario they applied is related to a chassis welding process in which the operator has to supply the components (parts) which are then welded by an industrial robot. The prototype presented here was used for operator training but can also be a tool for analyzing workplace ergonomics or an interactive monitoring platform for maintenance work or production flow operation. In the future, the applicability of the platform will be extended to various other manufacturing areas and new forms of virtual environment - real environment interaction will be implemented.

6. References
[1] Farshid M, Paschen J, Eriksson T, Kietzmannc J 2018 Go boldly!: Explore augmented reality (AR), virtual reality (VR), and mixed reality (MR) for business, Business Horizons 61 Issue 5 p. 657-663.
[2] Salah B, Abidi MH, Mian SH, Krid M, Alkhalefah H, Abdo A. 2019 Virtual Reality-Based Engineering Education to Enhance Manufacturing Sustainability in Industry 4.0 Sustainability 11(5):1477.
[3] Eschen H, Kötter T, Rodeck R, Harnisch M, Schüppstuhl T 2018 Augmented and Virtual Reality for Inspection and Maintenance Processes in the Aviation Industry Procedia Manufacturing 19 p. 156-163.
[4] Numfu M, Riel A, Noel F 2019 Virtual Reality Based Digital Chain for Maintenance Training Procedia CIRP 84 p 1069-1074.
[5] Berg, L.P., Vance, J.M 2017 Industry use of virtual reality in product design and manufacturing: a survey Virtual Reality 21 p. 1–17.
[6] Lipton J I, Fay A J, Rus D 2018 Baxter’s Homunculus: Virtual Reality Spaces for Teleoperation in Manufacturing IEEE Robotics and Automation Letters 3(1) p. 179-186.