# Virtual and augmented reality technologies in virtual industrial learning worlds: research and application

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*Abstract* — **Virtual and augmented reality are highly developing technologies which finds an application in many life spheres, particularly in educational process and manufacturing. It features real-time image changing and experiencing the presence effect. Moreover, manufacturing companies have been facing challenges particularly related to volatile demand and changing requirements from customers and suppliers, requiring new technological roadmaps in manufacturing systems. In this context, such innovative technologies as virtual and augmented reality support workers-aimed information processes creation. With this in mind, augmented and virtual reality can be adopted for workforce training. The hardware and software system implemented and based on the virtual reality technology provides the student with full immersion into the learning process of complex technical objects assembling, which leads to a greater understanding of the technical object structure, assembly success and reduced assembly time.**

*Keywords* — *virtual reality, virtual trainer, e-learning, unity, 3D modelling*

## I. INTRODUCTION

Nowadays, manufacturing companies are facing challenges related to ever-changing demands from customers and suppliers [13]. These factors are also known as "the fourth industrial revolution", or "Industry 4.0" [14]. It refers to new production patterns, including new technologies, productive factors and labour organizations, which are completely changing the production processes and the relationship between customer and company with relevant effects on the supply and value chains. Manufacturing is switching from mass production to mass customization which means that manufacturing is based neither on scale nor volume effects, but on flexible and localized production situated close to customers. It is more predictive and auto-corrective and it involves less trial and error. In this proactive context characterized by volatile demand, changing requirements and product variants, innovative technologies can support the creation of information processes aimed at workers. The human workforce is integrated in the manufacturing systems

and it too must be flexible and adaptive [15]. With this in mind, augmented and virtual (A/V) realities can be adopted for workforce training, with the result of a better human-mahcine interaction.

Augmented reality allows to display the needed information at the right time and to locate it in the desired space, superimposing it to the real world. In this way, it could simplify the work of industrial operators in a variety of tasks, from planning and commissioning to assembly and maintenance [17].

Among the set of computer technologies supporting the educational process, virtual reality (VR) has specific features, which have enormous potential and provides education process with the effectivity in most areas of human activity.

VR is the most promising technology for providing new learning and education solutions and more efficient opportunities for a revolutionary training environment [11].

Curricula created on the virtual reality technology base are universal in the software and hardware context, it easily integrates into the traditional educational process and allow replacing real objects with their interactive simulating models that help students, trainees to immerse themselves in a professional environment.

Thus, advantages of using virtual reality technology in the learning process are the following.

- the entire spectrum of human receptor systems is used at once, hence a coordinated process of transmitting information through several channels at the same time is organized;

- man can fully immerse himself in the created environment;

- knowledge and skills are interactively acquired.

Education using virtual reality makes it possible to conduct lectures and seminars, to show students all aspects of a real object or process. VR technologies make it possible to fully

use the fact that a human receives 80% of the information from the outside world through vision, while people remember 20% of what they see, 40% of what they see and hear, and 70% of that what they see, hear and do [10]. The use of innovative technologies is updated in the educational environment with the aim of optimizing the study of disciplines, increasing the professional adaptation of students.

All these facts mean that virtual and augmented reality can support shop-floor operators, implement virtual training for assembling processes, support advanced diagnostics integrated into the modules etc [16].

## II. RELATED WORKS

In [5] training operators simulators are described. The author divides them into two large groups: the first group is for console operators working with distributed control systems, the second group is for field operators that perform on-site control.

In contrast to the traditional 2D simulator interfaces, the VR achieves a fundamentally different level of similarity and immersion depth. At the same time, according to the author, there are dangerous moments associated with VR simulators: firstly, the gaming moment reduces the responsibility level which is necessary for the operator in real work, and secondly, the cost of such a simulator and its support can be very high.

In [8], applications for mobile devices are studied, which allow transmitting the image from the device screen to physical and software receivers. It is noted that these applications are platform-dependent, that is, they are only suitable for devices based on a particular operating system, there is also no way to select a viewpoint other than the position of the operator's head in BP, and adjust the proportions and sizes of the image capture area. The author offers his own virtual reality application developed on the Unity game engine for Samsung GearVR and Fibrum glasses, based on a client-server model. Two approaches were used to implement the application: in the first, the server is located on the mobile device, in the second, the virtual scene is completely processed on the external production server, after which the generated stereo pair for each frame is transmitted to the VR helmet.

Simulation tools are described in [12]. Authors use the «Teacher center» approach in which teachers write the scenario according to stakeholders' queries. A trainee deals with «virtual tablet» as a helper, a lot of guidance visual features are applied. Also, the experiment was carried out in a sales area where most students (90% of the test group) were initially sure to progress with VR tool and found it really useful.

Actively ongoing development in the creation and modification of virtual reality devices. In [4], a conceptual diagram of an enlightened head-mounted display was proposed, consisting of a microdisplay for playing a virtual scene, a projection lens with a swivel mirror, and a mirror eyepiece.

## III. HARDWARE AND SOFTWARE

In the Education and Design Innovative Technologies Laboratory, IDDO UlSTU, research, design and implementation of computer simulators using virtual reality technology are being done [1][2].

The hardware equipment is represented by HTC Vive™ headset, including VR helmet, two joysticks, two base stations designed to configure the real space in which virtual reality will be simulated.

An important difference between HTC Vive™ headset and analogues is the presence of a built-in front camera, due to which, at any time, by pressing a special button, the user will be able to see the contours of the world around him right through the game and, without removing the headset from his head, communicate with people in the room looking at them on the virtual screen.

In this work virtual workplaces trainers created using the Unity game engine are researched. For programming the interaction between game objects and controllers, the SteamVR SDK software package is used. The advantage is that it contains a simple game scene inside which possibilities of the package are demonstrated so as to speed up the VR projects creation and modification projects process. The software package also contains a standard player object with configured camera parameters and game controllers. Thus, it becomes possible to build a project for VR glasses.

## IV. APPLICATION FEATURES

As was stated before, virtual workplaces are created with the Unity game engine [3] which, in turn, provides the ability to build VR projects.

The possibilities of using virtual glasses were tested on the example of a fitter virtual workplace. In particular, prototype was developed with basic technological operations for installing elements on a textolite frame.

SteamVR SDK software package is used for programming the interaction between game objects and controllers. Key scenarios are Interactable script, containing event handlers associated with the touching of an object by the controller and Throwable one, processing the physical interaction of the game object and the controller. The latter script automatically connects Interactable, Velocity Estimator and Rigidbody components (Figure 1). If it is necessary to move around the scene, teleporting scripts are applied to implement the functionality (Figure 2).

While developing VR simulators it is worth taking into account features of the subject area and risks that may occur when modeling scenes and objects.

In Figure 3 the virtual workplace of a fitter of radio electronic equipment is shown. The simulator provides the function of displaying the item name when the controller is hovering it, since it is not always possible to read the inscriptions on the product 3D model via VR glasses. Source code switching the help information is shown in Listing 1.

```
using UnityEngine;
using Valve.VR.InteractionSystem;

public class InteractableC1 : MonoBehaviour
{
    private TextMesh textMesh;
    void Awake() {
        textMesh =
GetComponentInChildren<TextMesh>();
        textMesh.text = "   ";
    }

// Showing object name when beginning controller
hover
    private void OnHandHoverBegin(Hand hand) {
        textMesh.text = "Конденсатор К75-47-6,3кВ-
0,22мкФ ± 10%-В";
        }
// Hiding object name when ending controller hover
    private void OnHandHoverEnd(Hand hand) {
        textMesh.text = "   ";
    }
}
```

Listing 1. Switching object name depending on hovering the controller

In Figure 4 the virtual workplace of the radio mounter is shown. Here the trainee has to deal with radio elements, the sizes of which are much smaller than the size of the controllers. The solution is to conduct a focusing beam from the controller, "capturing" the first object in its path, with which the trainee interacts.

Similar solution is used in a virtual training ground – polygon – for calculating the air defense systems characteristics (see Figure 5) [9]. This simulator provides the ability to navigate the virtual section of the map and deploy air defense facilities and groupings of troops.

## V. NEW AND TRADITIONAL LEARNING METHODS COMPARISON

The computational experiment is carried out, it has a goal to evaluate the effect of applying a new learning method using VR. The measure of the effect is, firstly, the reduction of time taken to do the technological process on a concrete virtual workplace. Also change of motivation level of trainee to continue working on these workplaces and upgrade themselves is measured. It has value of 0 if a trainee is not motivated to get a worker job and value of 1 if he got to work in this field seriously.
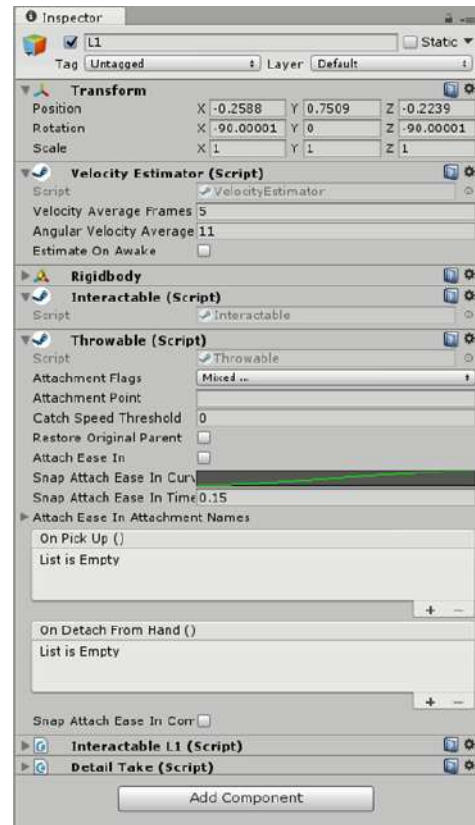


Fig. 1. Basic game object components in VR project: *Interactable*, *Throwable* and *Velocity Estimator* scripts
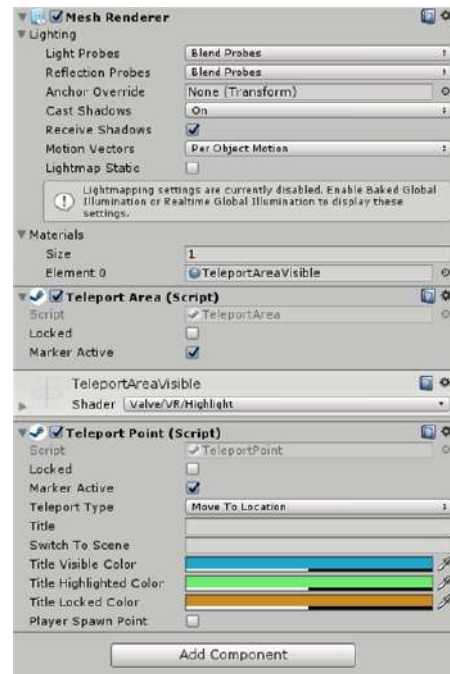


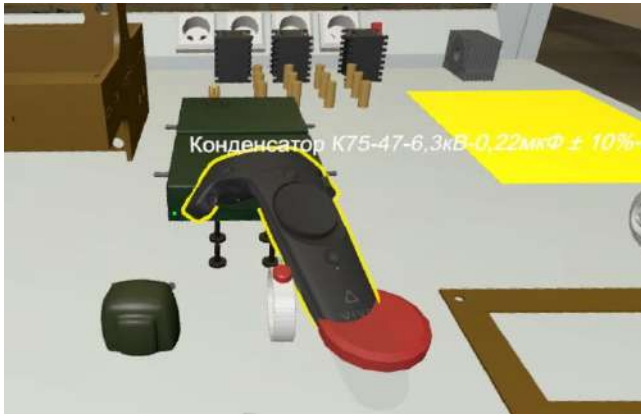Fig. 2. Basic game object components in VR project for teleporting

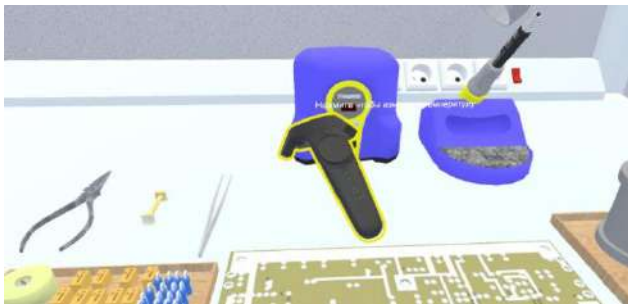Fig. 3. Radio electronic equipment fitter virtual workplace



Fig. 4. Radio electronic equipment mounter virtual workplace

Virtual workplaces of radio mounter and fitter are proved in the experiment. For each experiment part samples including 30 trainees have been prepared. The first group was initially studied with traditional methods without VR trainers. Their results are shown in Table 1. After that the second group was studied with VR technology additionally. Results of this group are given in Table 2.

TABLE I.        TABLE CAPTIONS SHOULD BE PLACED ABOVE THE TABLE

| Metrics | Average metrics value | |
|---|---|---|
| | *Radio mounter* | *Fitter* |
| Technological process doing time, minutes | 9 | 7 |
| Motivation level | 0,4 | 0,45 |

TABLE II.        METRICS OF TRAINEES TAUGHT WITH STANDARD METHODS AND VR TECHNOLOGY

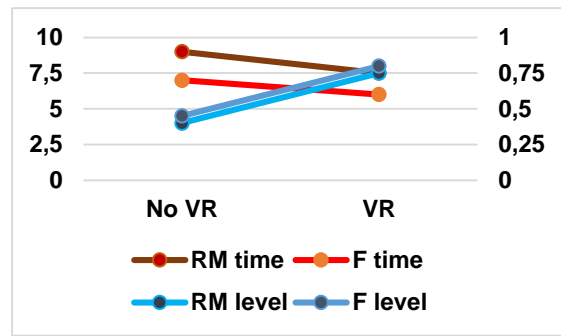| Metrics | Average metrics value | |
|---|---|---|
| | *Radio mounter* | *Fitter* |
| Technological process doing time, minutes | 7,5 | 6 |
| Motivation level | 0,75 | 0,8 |



Fig. 5. VR implementation experiment results

Comparison results on diagrams on Figure 6 show that motivation level after applying VR trainers of radio mounters (RM) and fitters (F) has arisen on 80 % and technological process doing time reduced on 15 %.

## VI. CONCLUSION

Industrial AR applications have specific constraints that can lead to application barriers. The general requirements for AR systems [13] can be met to a large extent for the applications considered, but there is still considerable room for improvement. Especially with regard to the reliability, fulfillment of work safety regulations and overlay accuracy of the systems. This is mainly due to the current AR hardware used for the applications considered, which does not yet have a high degree of technological maturity. The cost-effectiveness of the AR systems can only be reached by time or resource savings, due to the comparatively high costs of capable AR hardware.

Also it would be incorrect to think of VR as a new technology, because works on it began back in the 60s. [8]. Nevertheless, the researches and products, which seemed fantastic decade ago, is real today and already applicable in most life spheres, especially in education. In particular, they are used in the training of future specialists in areas where stereoscopic representation of the studied and researched objects is necessary: from stereometrics and 3D graphics to aviation and astronautics [6][7].

The considered features of VR development and results of experiments showing studying time reduction on 15% and motivation level rising on 80% allow us to conclude about the need and effectiveness of their use in the modern educational space.

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