New approach of designing robotics production systems using immersive virtual reality environment

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Abstract. Production requirements are growing and companies needs to adapt to the latest trends with state-of-art technologies. Virtual reality (VR) technology promises big changes in Industry sector, even this technology is still evolving. This immersive technology allows to visualization and interaction of complex engineering data in virtual environment, provide various inspection of 3D objects and allows to communicate changes on objects or process between production teams and customers. This paper discuss about potential of VR systems in Industry and purpose of usage to improve development process and the use of this technology in the design of future robotic systems. The goal is to compare causal designing methods of robotic work station and method with using VR environment and their possibilities. Development supported by VR systems shortens pre-production phase and brings to user immersive experience with designing product or process without creating physical prototype or real production systems.

1 Introduction

Simulation tools for production optimalization becomes more important in time of Industry 4.0. Computer aided simulations are used to make whole production system more efficient and competitive in global market. It also provide faster development of new products or methods and save money [1]. However, there is still a lot of optimalization problems during a development process, which can be solved by using correct simulation tool, such as Virtual reality (VR).

VR is a system that provides manipulation of three-dimensional objects and allow to perform multiple actions in immersive digital environment. Even though VR is in early stages, it is more and more used in industrial sectors and companies are finding way to usage [2]. This technology promises benefits for industrial applications such as model prototyping, simulations of processes, maintenance tasks and design review. Nowadays high-quality VR devices perform 3D visualisation with minimal programming knowledge of users. However, visual objects and environment rendering is satisfying, haptic feedback and interactions are still difficult [3].

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In this paper we discuss new approach of using VR in industry area. Main research is aimed to simulation of robotic workplace with using immersive environment during design phase to demonstrate potential of this technology. Actions like replacing objects, measurement or guiding robotic arm are compared with actions made in simulation programme Process Simulate. Comparison contains possibilities of both methods and their advantages and disadvantages.

2 Definition of Virtual Reality

Virtual reality is a set of technologies, which sense the state and operations of users and change it into feedback information that makes users more involved into simulation environment [4]. Aim is to convince users that they are inside simulation environment physically or feel sense of presence [5]. To achieve the best experience, VR must react on input information in real time. This is one of the main conditions for the best experience. VR is sometimes referred as immersive computing technology (ICT) to interact with ever-evolving digital environment [5].

Key elements to achieve immersive VR experience are following characteristics [6, 7]

Virtual world - Collection of objects controlled by relationships and rules in computer-generated environment.

Immersion – Feeling of users to be involved into virtual space and freeing their mind from physical world.

Feedback – Gives users ability to see and feel the results of their activities in virtual environment. To ensure feedback users have to use additional equipment e.g., controllers, speakers and suits.

Interactivity – Possibility to interact with virtual world. For example, equipment such as controllers and gloves allow users to grab and replace objects in virtual environment.

Participants – People using VR device to manipulate and interact in virtual world.

VR Systems are made up of many components. We can divide it to three basic categories depending on their purpose. First category is **output devices**. Their purpose is to visualise virtual environment for users such as Cave Automatic Virtual Environment (CAVE) systems or Head Mounted Display (HMD). Another output device is made also for tactile feedback. Second category is **input devices**. We can divide this category into three subcategories. Main input category is *Controllers*. They allow user to interact with virtual world by using buttons and triggers. Next subcategory is *Navigation devices* to get better and more intuitive movement experience in virtual environment. To last subcategory belongs *Tracking devices*. They can track body or hand movement in space. Mostly they are implemented in devices such as hand controllers and suits. Last category is **Software package**. We can divide it into two groups by application. First group is runtime environment. This ensures communication between software and hardware of device. For example, Steam software provide runtime environment for HMD device such as HTC Vive. Second group is VR engine. With help of engine is VR able to create virtual environment. For example WeAre, techviz or virtualis [7, 8]

For improving realism of VR systems, we need to develop more effort and research to achieve following objectives. HMD devices need to reduce weight to be more comfortable to wear it. Latency effect of protection system and cost of device needs to be also reduced. Devices needs to increase robustness and increase display resolution and field of view. Sensors needs to be less invasive and more intelligent to be able to capture not only a motion but also human emotions. For example, stress level. Haptic devices should generate force and tactile stimuli for better feedback for users. Users should properties of touched object such as shape, texture of surface or softness/hardness. At least software

equipment has to improve algorithms of physical and geometric data. This will improve organizing and manipulating [9].

VR systems do not bring us only a pleasant feeling and bring us only a benefit. In some cases, this system can be also harmful for our health. While we use VR, accuracy of movement does not response with real movement of human body. Then our brain has conflict with senses inside virtual world and outside of it. Users can have various symptoms such as motion sickness, disorientation, nausea and headache that can leads to vomiting. To avoid these symptoms VR systems must be improved by higher framerate. This leads to decrease symptoms from 10% do 20%. In some cases it can be 50% [10]. Higher resolution and accuracy of movement also helps reduce these symptoms.

3 Virtual Reality in Industry 4.0

Since first time was VR used in industry, lot of researches and experiments were made. Companies made significant progress in usage of VR and expanded usability of VR systems. Now it is presented as valuable tool for improving production and services. The biggest benefit of VR system is testing factors that influence production process such as production time, quality of process, trainings, development etc. This leads to reducing of errors during production and save time and money.

To achieve objectives mentioned above, companies use VR systems for:

Decision making - Engineering work in industry is based on communication and decision making. Mainly decision making becomes complicated and influenced by increasing technical complexities, time and budget pressures and lack of experienced workers. The most of product design is made in digital form and State-of-art design tool becomes an obstacle for people outside engineering community which leads to communication barrier. VR system offers great tool to check design, even not all users are able to use CAD software used for design. Moreover, VR add more comfortable way to interact with objects and validation of ergonomics. This way of visualisation simplify process of decision making [3].

Collaboration – Interdisciplinary teams working with VR systems replace physical models by digital mock-up. This allow to make changes where is needed in safe environment without potential risk. Engineers with help of simulation software are able to solve issues related with manufacturing and cut the cost by creating and testing components in simulations before they are made physically. Companies use VR system to collaborative design reviews to optimize production process (such as assembly or disassembly) and verify. Manufacturers are able to identify problems during manufacturing process, resolve it in real-time and communicate it with other members of team. This means that development process is faster, more comfortable and reliable. Also errors are reduced, work-flow is simplified and overlooked problems are minimized [3].

Training – VR training systems substitute real experience by guided and immersive way of process learning in virtual interactive environment. It helps to improve performance and reduce errors. Training and education via VR systems has been shown as effective way to learn and to achieve better outcomes. Students stay more focused on tasks, inspire and motivate to interest in learning. They also pay more attention and they are more concentrated. We can find this way of training not only in industry but also in medicine, military, firefighting, airplane safety and more [11].

4 VR as a prototyping and simulation tool

VR is increasing usability as a prototyping tool. Construction, engineering and architecture industry are mainly involved, but more important role of VR is in mechanical

engineering and product development. VR able to see prototypes in virtual environment before they are produced physically. It reduces the count of manufactured prototypes and also allow to publish pre-release version of prototype. This allows users, suppliers or external customers to participate on prototype development process, decrease cost and reduce development time [12]. Furthermore, maintenance work or assembly can be also simulated. This include required activities and risk assessment [7].

CAD software are heavily related to alphanumeric data input and widget interaction which are controlled by mouse and keyboard. Researches proved that if we substitute keyboard input with vocal one it will enhance design activities in virtual environment [13]. The most recent researches proves that using of multimodal interfaces in VR applications ensure lower execution time and better accuracy [14].

VR can improve process, determinate parameters and variables included in the simulation. For adaptation of VR simulation for specific scenario, we need to know all requirement of input and output devices. Visual output devices and their process requirements are rated by selected criteria and scenarios involved in simulation. Visual output devices are rated by following criteria (Fig. 1.) [15]:

Field of View – Increasing immersion effect of VR device.

Ease of maintenance – In general, the more components VR system contains, the more maintenance is required. In addition, more knowledge required to control the device. This may lead to increasing cost and delays.

Mobility – Size of device, time required for assembling or disassembling VR system and transportability are main factors for using VR outside development team lab. For example, external presentation of product in customer's company.

Immersion grade – For the more experienced simulation is immersion grade important factor. To achieve bigger degree of immersion, VR system must contain device with possibility of interaction with objects, movements must be transformed to virtual environment and secure suitable field of view.

Number of users – For multiple users in one virtual environment must be secured fault-free stereo image for all users. In addition, they must be able to communicate in virtual environment by using their voice [15].

Fig. 1. Evaluation of visual output devices [16].

5 Experimental procedure

This procedure consists of creating robotic work station for welding and placement operations with support of VR device, to speed up and simplify designing process compared to causal method. Causal method is creating offline simulation in software such as Process Simulate (PS) or ABB RobotStudio. This simulation programmes have some

programming standards, which can be improved by using VR immersive environment. For this experiment, we use simulation programme Process Simulate and VR device HTC Vive (Fig. 2.).

Fig. 2. VR simulation environment in Process Simulate software displayed by HTC Vive.

5.1 Field of view

The most of standard CAD software dispose with two view modes – Parallel and Perspective. These two modes can be changed as user need to visualise current object. As the number of objects in environment grows, for example whole robotic work station, there is a bigger need to visualise more object in field of view. We made a comparison of field of view in simulation software PS (Fig. 3.) and in VR environment (Fig. 4.). VR provide bigger angle of view. Thus, we can see more objects and prevent some risks such as collision in a phase of creating paths for robot motion.

Fig. 3. Angle of view in Process Simulate.

Fig. 4. Angle of view in Virtual Reality environment.

5.2 Robot reachability verification

Making a layout of all workstation components is very important part of designing phase. Robots have to reach every target location and avoid static obstacles in its work area.

Causal way to verify, that target locations are reachable for robot is to use tool “Reach Test” (Fig. 5) or “Smart Place”, but these tools can’t show us tool in target location, only that the location is reachable. Thus, we know if we can reach location, but we can’t see possible collisions or problematic places. Last option is to manually set robot tool to every location, which can take lot of time.

In our case, we verified locations for handling and welding operations (Fig. 6.) to test reachability in VR environment by using haptic controller. This controller track motions of our hand and enable manipulate industrial robot in its Tool Centre Point (TCP). The controller does not sense movements only in X, Y and Z axis, but also rotations around these axis as we turn our hands.

Fig. 5. Reach test.

Fig. 6. Robot reachability of weld points.

5.3 Manipulation with objects

In case, that we cannot reach some of target locations, there is a need to move objects such as work table or industrial robot to be able to perform its operations.

Simulation programme offers us classic placement tool (Fig. 7.) to move objects in X, Y, Z axis, rotate around them or free movement by drag and drop. This way can be tricky, because we have to perform lot of changing angle of camera to be sure, that model is in correct height or distance.

VR allows us to grab a component and change its position in the same way as in case of robot tool (Fig. 8.). Advantage comparing causal method is, that recognition of model distance is much easier, because we are in same environment as model.

Next step is making a precise position in CAD software, because VR module of PS does not support manipulation with precise coordinates.

Fig. 7. Object manipulation in PS.

Fig. 8. Object manipulation in VR.

5.4 Measurement

Another useful function is measurement. Measurement compared in simulation programme (Fig. 9.) and in VR environment (Fig. 10.) makes not big difference, but VR has one advantage. While creating dimension in PS, we choose two points or planes and create dimension between them, in VR dimension is shown immediately as start point is set.

In our case, this function was used mainly for safety and work zones. After placing all station components to correct positions, we had to allocate zones to secure safety for station

operator and avoid risks, that can be happened during work. For example, if someone stick fingers through fence holes, robot cannot reach this place and harm operator. To get this safe dimension between robot and fence we set robot to the closest position during its operation and measured dimension. Measurement is made by pulling the trigger at the start point and release in the end point. Dimension is shown immediately as start point is set.

Fig. 9. Measurement in PS.

Fig. 10. Measurement in VR environment.

6 Conclusion

Expected contribution of this paper is to show possibilities of designing work station for simulations in different way than is causal via CAD software. Designing with VR tool appears to be future for simulation because of abilities, we cannot perform in CAD software. Also, this way is easy to handle and allows users to work on station layout, with no need of knowledge of complicated simulation programs. Even VR is in early stages, we can already consider it as a valuable tool for designing and verification processes.

Future research: Authors want to focus their research on expanding the possibilities of VR especially for the design of new production systems with the application of robotic systems. Thus, take advantage of the possibility of programming industrial robots in the VR environment as well as layout solutions in the form of design layout of machines, equipment and robots in the VR environment.

Figure 11. shows QR code of video from using VR in practice, which can be read by smartphone or any other device able to read QR code.

Fig. 11. QR code of VR practice in Process Simulate.

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