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ONLINE AND OFFLINE CONTROL OF COLLABORATIVE ROBOTS USED MIXED REALITY

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Abstract: The presented article points to the combination of mixed reality with advanced robotics and manipulators. It is a current trend and synonymous with the word industry 5.0, where human-machine interaction is an important element. This element is collaborative robots in cooperation with intelligent smart glasses. In the article, we gradually defined the basic elements of the investigated system. We showed how to operate them to control a collaborative robot online and offline using mixed reality. We pointed out the software and hardware side of a specific design. In the practical part, we provided illustrative examples of a robotic workplace, which was displayed using smart glasses Microsoft HoloLens 2. In conclusion, we can say that the current trends in industry 4.0 significantly affect and accelerate activities in manufacturing companies. Therefore, it is necessary to prepare for the arrival of Industry 5.0, which will focus primarily on collaborative robotics.

1 Introduction

Today's trend in technology development is growing at a progressive pace. It is evidenced by the increase in augmented, virtual and mixed reality, namely 23% in industry. Mixed reality (MR) can be on different screens, devices, smart glasses, smartphones, tablets, or even computers. The main element is the camera, which complements the real environment. It is used to improve the perception of the world by integrating various aspects. Displays visualization of the assembly process, video, text instructions and production status update. However, it is also used in multiple fields [1]. For example, industry, automation, education, medicine, logistics, warehousing, aviation. Virtual Reality (VR) - is a technology that simulates a computer-generated environment and gives the user the feeling that he is in that environment. The main tool is headsets, which create a stereoscopic image so that what you see is three-dimensional. They send out completely immersive sounds and sensations to get you to another place where you can communicate with this world. The presence of a person who can move and manipulate objects is simulated. Augmented reality - the main difference from virtual reality is that we see the real world in which artificially created elements are displayed directly into the environment in front of the user. It offers immediate access to information, making it an important application in the industry. This real-world implementation is most often done through smart glasses because they are the most used devices. Of course, it is also functional on ordinary smartphones and tablets [2].

Mixed reality - This reality is one of the innovative solutions to augmented reality. There are three different types. Virtual reality gives you a glimpse into the digital world through a headset. Augmented reality allows you to insert objects into the real world using mobile and other devices. Mixed reality, also called mixed reality, is a step forward, taking it extended to the next level, where we can manipulate images embedded in the real world [3,4]. An example is Microsoft Hololens2, a device that provides us with the real world, but we can integrate with real and virtual objects and create new things or adapt.

In this article, we focus on implementing the already mentioned mixed reality about collaborative robots as companies begin to discover the benefits of collaborative robots. There is more and more talk about operator facilitation, precision, speed and safety. In the eyes of concerns, automated production looks significantly more reliable [5]. The automatic robotic process is more stable, offering more security than the manual process. Robots are part of Industry 4.0. They take over monotonous and hard work from people. Even many robots have an RFID chip in them. They send data to online storage via the Internet of Things as other elements of a smart factory [6]. Such cooperation brings greater flexibility and productivity. All robotic cells must be subject to and meet a safety standard. Over the last 30 years, the average price of robots has halved. Time is running out, and this is reflected in the robots. New safety and construction elements of robots are created, such as speed and torque sensors, round shapes, weight reduction, intuitive movement, soft layers of robots.

With these improvements, development is progressing at a progressive pace. It is assumed that in 2024, a third increase in the integration and sales support of these robots is expected [7].

1.1 Collaborative robots

The first idea to build a collaborative, collaborative robot originated in 1995 as part of the Generals Motors project. From this period, these systems began to be used massively. The advantage of conventional robots is that they work directly with humans. They help with demanding operations, such as screwing in difficult places or handling heavy parts [8]. The aim is to free people from dirty, boring and dangerous work. They are becoming an increasingly common modern attribute, with a gradual reduction in human labour. Robots have great power, so they must comply with the ISO / TS 15066 standard from the point of view of safety. It includes [9]:

1. Manual guidance **-** After the operator has travelled the critical path, the worker teaches the robot this movement, and it repeats it. When the button is pressed, it switches from automatic mode to manual mode. In automatic mode, it stops when a person enters the robot's path for safety reasons.
2. Safety stop sensor **-** Protection of safety and health at work comes first. There is a greater risk in processes where there are higher machining temperatures and higher loads. The number of these sensors depends on the type of operation and equipment of the robot. In the event of a stop, the process restarts after pressing the safety button.
3. Speed and distance monitoring **-** The robots have defined safety zones. If an unknown body approaches an object, the automatic joints slow down until it stops. Robots with this function do not have to be protected by a fence or be in a cage. Unlike the stop sensor, they do not need a physical button press to restart. Safety zones control the operation of the robots.
4. Power and power management**-** It is a combination of technology monitoring various parameters. All these properties prevent the pressure on a person from exceeding the set limits. These forces and moments are specified by the mentioned standard ISO / TS 15066.

There are already many collaborative robots today. Specialists in the field take care of their installation and programming. It takes several weeks to launch these robots. This cooperation brings greater flexibility and a growing degree of the practical application of the industry concept 4.0 processes [10].

2 Methodology

For our purposes, we used a two-armed ABB Yumi collaborative robot, which is available at SmarTechLab for Industry 4.0 at the Faculty of Manufacturing Technologies, with the seat in Prešov of Technical University of Košice.

2.1 Collaborative robot ABB Yumi

The intelligent ABB Yumi double-arm robot, in short, you and me, offers an innovative ergonomic design focused on people for collaboration. The Yumi was designed mainly for smaller parts and fast handling, thanks to two arms with seven degrees of freedom. It can handle 0.5 kg of payload. Due to its lightweight components, it can work with high speed and accuracy. ABB's growing Yumi robot family is part of exciting collaborative automation solutions that help people work together safely [11].

Figure 1 ABB Yumi

ABB Yumi has found its application in various activities on the market in 5 years. It is a handy solution of 2 arms working independently with seven degrees of freedom, which means 14 axes. It is designed for delicate and sensitive work rather than for small structures with a load capacity of only 0.5 kg. The degree of protection is IP 30. It is recommended to work in a clean environment. Yumi can perform the same tasks around with great accuracy with position repeatability of up to 0.02 mm and a maximum speed of 1.5 m / s.

All types of robots at ABB have their technical parameters. Among the basic specifications of kinematic mechanisms as a whole are technical properties. These include the following technical parameters [12]:

Degrees of freedom - this is the number of independent directions in which the robot's joints can move. It's the flexibility of the robot. Most Abb robots have 6. The unique YuMi, or IRB 1400, has 14 because it contains two arms with seven degrees of freedom.

It reaches the greatest distance that the arm has from its axis or the robot's working space. The range ranges from 500 mm to 4 meters, depending on the work function and size. For example, the YuMi robot does not excel in the long field, but it often catches up over work speed.

Load - this data indicates the maximum load capacity of the robot's end mechanism, with which we can attach, transfer or manipulate the material. The full load depends on the type and size. Devices with a higher load capacity are rather used for handling and palletizing large loads.

Protection - there is a big difference in the environment in which the devices work. Either in a clean environment or extreme conditions. The IP parameter presents this value. Currently, several robots normally meet IP30 / 40, which must be resistant to water, dirt, dust and unwanted dirt, so they meet the requirements of IP67. Painting robots have special IP67 EX protection.

Repeatability - the more accurate the cyclic activity of a given task. It is offered in tenths and hundreds in mm. The influence of acceleration and deceleration provides the term maximum speed. Repeatability numbers range from 0.01 to 0.20 mm.

Usage - ABB has a solution for every industry. So every robot has its spectral use. The better the repeatability of the application, the better the accuracy. Larger robots are usually stronger and more suitable for handling heavy loads. Smaller models are faster, more responsive and unobtrusive. Their main task is to free people from hard work and speed up the production flow.

2.2 Microsoft Hololens 2

Microsoft Hololens 2 is a new vision of work, a new reality in computer technology. It is an updated version of the augmented reality predecessor. Microsoft has worked on some suggestions from users. By enlarging the field of view or by observing the movement of the eyes. A novelty is an eye-tracking function to improve the handling of the hologram. After pressing the holographic button, you can close the instruction sets, start the video or the program. The comfort and convenience of wearing a headset have increased. They make a more convincing impression than their predecessor [13,14].

Hololens 2 is for professionals rather than home entertainment. The target will be companies and various industries with a price tag of $ 3,500. There will also be the possibility of borrowing $ 125 for one user in the company. Such a solution will not burden the company's cash flow. Developers create new offerings—for example, Azure's mixed reality services, such as smart cloud for collaboration. Also, a proven Unity 3D platform with enhanced benefits. Anyone can join a local user group with an open-source project to create mixed reality applications.

Figure 2 Microsoft Hololens2

2.3 Software support RobotStudio

Online manipulation occurs directly at the workplace if the robot is directly connected or in operating mode. There are several types of programming through manual guidance by entering technological, tool and motion coordinates. Another variant is via the Teach pedant unit. It is a device that is used to control a robot. Up to 90% of robots are managed in this way.

A play-back method records the movement by which a person moves with the robot's joint and thus guides the entire technological process manually or copy the path. The last to choose is a text control with commands. Programming is performed in a real environment. It is possible to check for possible errors and prevent potential collisions immediately [15].

Today's trend is more concerned with offline programming in reducing machine times in current automated environments than they say time is money. This technology must be geometrically accurate by comparing the nominal values with the actual state. This type of preparation, imitating the work of a robot, allows you to work without the condition of stopping production, which maximizes the productivity and operation of equipment [16].

The disadvantages include the purchase of additional investments outside the robot to ensure a virtual environment. This program is mentioned RobotStudio, which allows us to create robotic activities offline on the necessary equipment. We can import CAD models and thus configure the required structure.

It determines the positioning of handling points and extreme positions in a measuring system that measures the role of the axes in the joints of the robot. Manufacturing inaccuracies and total deviations of the entire working drive are not taken into account. It is advisable to choose points that are not in extreme positions. Because at the greatest possible stress at the end of its range, the robot tensions the most, and this causes inaccuracy [17].

RobotStudio is a tool for programming, controlling, and simulating all collaborative robots from ABB or ABB Virtual Controller. One of the most used offline programming tools worldwide. With this program, engineers and designers can visualize, deploy, and test the operation of a robot to obtain important data. In RobotStudio, we can place physical surroundings and virtual objects, get as close as possible to reality. It is the same software copy that the robots control directly in production. Production does not have to be interrupted during use. The software contains a model of the control system with all the functions of an entire unit. The basis of all ABB controllers is RobotWare software. The programming language and system modules control the RAPID programming language, which has its commands and functions. In the following section, we focus on configuring Robot Studio with augmented reality. It works on the principle of running RobotStudio, which displays the basic functions of ABB RobotStudio, creating a new solution, adding robots, connecting tools, so-called. Controller either predefined or added using other CAD programs. For our purposes, it is necessary to run the virtual/augmented reality module, define a wireless network to which the collaborative robot and smart glasses are connected [18,19].

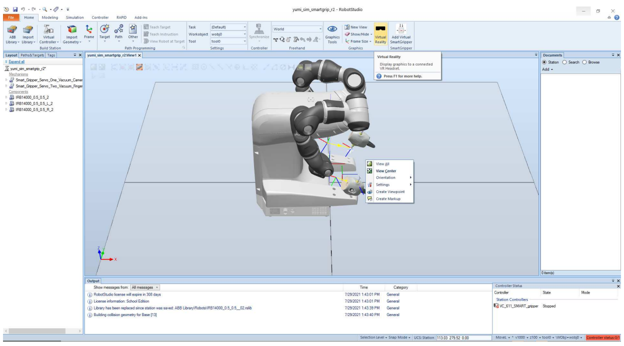

Figure 3 RobotStudio workspace and ABB Yumi location

In this article, we try to show the shift of collaborative technology in cooperation with augmented reality with the help of the RobotStudio Holographic platform and the main program RobotStudio, where we create a schedule, simulate or tune all the movements of the robot. The goal is to teach a collaborative robot to perform tasks using augmented reality. All this through devices that have the necessary compatibility, through which a person sees a robot and at the same time teaches him movements, or after programming, visual and movement control is possible with a virtual display in a real environment. In this way, we can configure the given domain and logistics of the production site. After defining the robot in RobotStudio, we will connect RobotO and Holopraphic to cooperate on the instruction to perform the necessary actions online, and offline from the entered commands. This will create an extended simulation pair working based on the use of augmented reality in real conditions. In Slovakia, economic robotics only in development, however, indicates enormous potential. The latest trend is the use of additive production, where new tools are required that need to optimize the trajectory. The mobile application represents the transmission of a visualization of the robot's course created in the Robot Studio. The commands needed to store and make this data, use the principles, protocols, tools and procedures were defined in RobotStudio and then imported into Robotstudio Holographics. The user can define all parameters.

3 Results

As already mentioned, the first step is to define the type of robot, specifically the collaborative robot ABB Yumi is referred to as IRB 14000. The standard library is referred to as IRB 14000 R **-** right arm only, IRB 14000 L **-** left arm only or IRB 14000 with both working arms. We set the selected robot type in RobotStudio. We start the part intended for control transmission, and we pair it with Microsoft Hololens 2 Smart glasses and RobotStudio Holographics application (see figure 4. We used software for live stream transmission of Microsoft Holografic as a tool for 3D view projection.

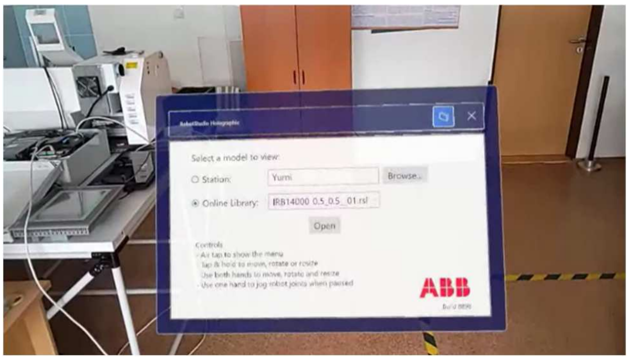

Figure 4 Launch of the ABB Yumi connection to the Holographic environment

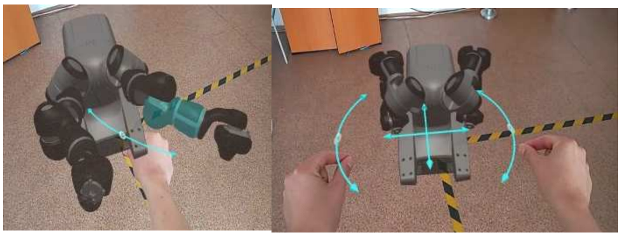

Figure 5 Illustration of ABB Yumi using MR

After pairing with glasses, there will be a real demonstration, a view in space, a holographic view of a 3D model. The object moves dynamically in space. If necessary, we can incorporate it directly into the production line but start it as a whole production process. In combination with ABB, it offers commissioning, where the recorded environment can be applied to the required technological method and navigate the robot to the required position or place. The specification of inputs and outputs is important.

We transferred the 3D model to cover the working field with a real robot in the next part. First, we tested the robot's movements in offline mode, where its task was to repeat the exact actions along a predefined path.

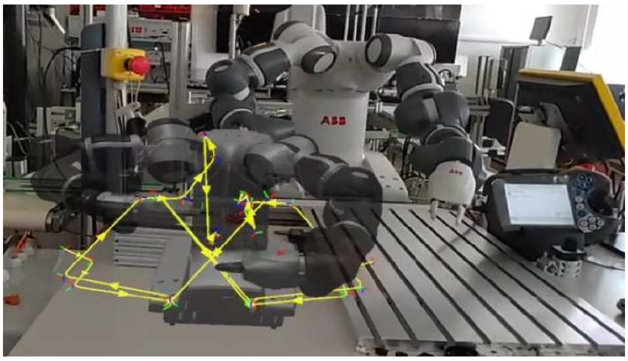

Figure 6 Offline robot test used AR

Following the start of the robot in AR and the definition of motion trajectories, we start copying the motion, and the robot repeats the real movements according to the 3D model. For online motion testing, we covered a real robot and a 3D model. After realising the movement, the robot repeated what we defined for him online with a small delay.

Figure 7 Online robot control in AR

We used ABB YuMi, Microsoft Hololens, Robot Studio and Robot Studio Holographics for the activity. The robot works with 2 grippers, one containing a camera. Control of vacuum grippers for suction and transfer of material to the selected transfer point, using learned hand movements and copying the trajectory of the joint communication of intelligent workstation components with augmented reality. Every movement is recorded and saved. The program records this movement in manual control, holds it in the procedure, and later performs this operation by an automated action.

Figure 8 Real work used collaborative robot ABB Yumi v AR

4 Conclusion

The purpose of this article was to point out the introduction and launch of mixed reality work in combination with robotics for manipulating a collaborative robot. The theoretical part deals with mixed reality, collaborative robotics. In the second part, we described the hardware and software requirements for implementing the experimental feature focused on online and offline control of ABB YuMi using mixed reality. This article points to a new portfolio of applications and technical solutions that can be implemented to date, for example, for educational purposes and for robotics exercises. This type of teaching makes learning interesting, interactive, and modern from the point of view of a new generation of students. The latest trend is RobotStudio Virtual Meeting, which provides a virtual room where participants can connect and monitor information and test the robot's installation in a 3D environment, thus deepening their knowledge in robotics. Mixed reality technology enriches the trainees by 80% more than in comparison with the traditional type of lectures. For education within intelligent technologies in the industry, we can integrate this novelty into exercises or elaboration of assigned tasks. Such a virtual lecture could save a third of the teaching time. As part of corporate training, we can halve teaching times. Mixed reality will support the Just in Time type of logistics to meet time and work requirements.

The aim and design of this article were to point out the use of augmented reality in collaborative robotics using smart glasses and RobotStudio. This simulation model allows us to implement the assigned tasks for performing robot movements on the automatic configuration platform. Specifically, start and transfer control of the robot's movements and speed up its commissioning by simulating the same cell created through the software. We designed the implementation of mixed reality directly with the control of the robot during the use of intelligent devices as a tool for manipulation, programming, and teaching purposes. The challenge was to connect all smart components to ensure compatibility and transfer of digital elements and their storage in the cloud and RobotStudio. The exact procedure and spectral use are described in the design part as the realization of mixed reality, together with real examples. This article proves that technology is advancing at an incredible pace, and we can take it with us. This means anywhere and anytime. We can control a robotic workplace. New trends such as mixed reality accelerate production processes and bring many benefits that are part of Industry 4.0 and the upcoming Industry 5.0.

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