



Augmented Reality as a Tool of Increasing the Efficiency of RFID Technology

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Abstract. The paper is focused on using the possibilities of implementing RFID technology with augmented reality. Today, it has become an element that is becoming more widely known. In this article, we gradually focus on two-second measures in two display units. The first alternative used for the measurement is the use of a UHF Bluetooth RFID reader with Smart glasses on the platform of the Android system. The second alternative is the use of industrial readers in Ethernet connection, its connection to the local wifi network and smart glasses Microsoft HoloLens 2. Both reading systems work on the principle of Ultra High Frequency, and therefore, different RFID tags are used in Label, industrial and metal case. For the laboratory measurements, we tested the reading distance of the RFID tag and the ability of intuitive control of applications. Based on the findings, it can be deduced that the implementation of augmented reality can help online monitoring and tracking the progress of production. As a concept, it is based on both proposals from the KANBAN system. The advantage is that suggested versions are mobile and can be directly implemented in manufacturing enterprises.

Keywords: Augmented reality · RFID · Concept of the measurement system · KANBAN · Smart glasses · Effectiveness · Competitiveness · Manufacturing

1 Introduction

The main idea of the proposed solution is based on the creation of a mobile system with which it will be possible to read radio frequency identification systems (RFID) in manufacturing companies. Based on recent experience with RFID systems, we can say that their loading is not problematic, but the problem occurs when displaying data in production. Many times it is necessary to provide a display unit that will be hardware and software compliant and can present the captured data. It opens up the possibility of using Smart glasses, which are gradually becoming known to people. These glasses work on the principle of using augmented reality and projecting the image into the work field. The fact as a concept is clear to us. It is all that we see around us undistorted and unadjusted. On the other hand, we may encounter a computer-edited and mediated reality that has been a great success in recent years. The following Fig. 1 shows the

basic division of mediated reality, where the main methods include virtual reality and augmented reality [1–3].

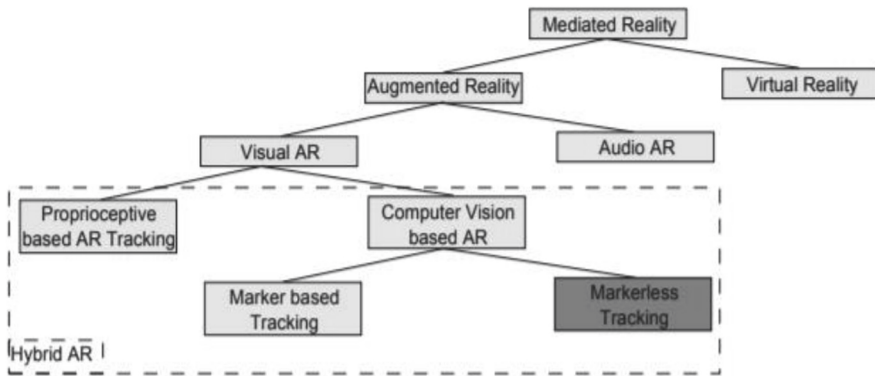


Fig. 1. Distribution of enhanced reality - distribution of mediated reality [authors own processing].

1.1 Augmented Reality

The meaning of the term “augmented” is something improved, expanded, added. In principle, the term augmented reality means a simple combination of a real and a virtual, computer-generated world. To clarify what this combination looks like, imagine a real object captured on video or a camera, where we use technology to “expand” this image in our real world with another set of digital information. Augmented reality obtains this information from various information sources using applications (off-line or on-line). In essence, this kind of reality presents us with a real (real) natural world enriched with elements of virtuality [4].

It is not easy to uniquely and generally characterize augmented reality as such. In this environment, we have the opportunity to grasp many different approaches and definitions, but to combine it into a simple characteristic, even given the ever-evolving technology, is bold. The extremely rapid development of technologies also has an impact on the development of augmented reality, both in the theoretical level and in practical use. During the constant development, the public was able to get acquainted with several personalities operating in the field of augmented reality. Prof. Steven K. Feiner, explains augmented reality as a way of the direct or indirect view of the physical environment in real-time, the elements of which are extended or added by a computer-generated sensor input, into which we include audio, video, GPS data, but also graphics [5].

Many researchers use the previous definition, but it also modifies it. One of them is the university professor Vladimir Geroimenko, who is based on Feiner’s theory and tries to understand augmented reality more comprehensively. “Augmented Reality (AR) is a real-time forced perception of the real-world environment that is tightly or seamlessly integrated with computer sensory objects” [6].

Lester Madden, like many others researchers, has created his view of augmented reality and the fact that, in its simplest form, AR is the art that perfectly overlaps computer

graphics and a vivid picture of the real world. Both of these worlds are very invisible [7].

Another important expert is Ronald T. Azuma, who in his work “A Survival of Augmented Reality” creates an overview of existing information found from various sources and publications until 1997, when this work was published. The generally accepted Azum definition states that the AR system contains the following properties [8]:

- Combines real and virtual objects,
- Registers (aligns) these virtual objects with the real world in three dimensions,
- Works interactively.

Canadian scientist Steve Mann, also known as the father of wearable computing, said that technology must be balanced on three axes - physical, informational and human. Also, by mixing all three, we can create an environment for users who do not select them from the physical world, but add layers of adjustments and adapt them [9].

Oliver Bimber and Ramesh Raskar present in their theory the main pillars on which AR technology is based. The basic elements include monitoring and recording, display technology and conversion, respectively a translation. Above this basic level are advanced modules, namely interaction devices and techniques, presentation and content creation. With the help of these elements, a suitable augmented reality technology can be found to serve the user [10].

Reality-virtuality continuum depicting the scale and connection between the two extremes is an interesting theory describing the environment of these realities. Before we define this scale of reality-virtuality, it is right to point out the difference and compare the augmented reality with its similar facts, as people in society often confuse it [11].

AR vs. VR

In any work on augmented reality (AR), it is necessary to mention its position in relation to virtual reality (VR). As mentioned above, the development of augmented reality and virtual reality is closely linked, but it is far from the same. Virtual reality is often defined as an artificially computer-generated simulation in which the user delves into a situation that does not contain any element from the real world. Usually, it is a pretended place that does not exist or it is a purely simulated reality. Let’s compare it with AR, which usually only adds imaginary objects (digital objects, descriptions, graphics) to the real image. We find that VR is not as similar as many people think. Virtual reality, like augmented reality, has a wide range of applications. It is popular among companies providing simulators, based on the principle of virtual reality, which help employees to learn the work environment sooner. Also, almost all games use virtual reality in their concepts. Computer-connectable headsets and stand-alone headsets are a means of immersing yourself in virtual reality. The goal of both of these realities is the same, to enrich the user for a better experience [12, 13].

AR vs. MR

MR as mixed reality, in translation mixed reality, is very similar to augmented reality and is not always easy to recognize. Mixed reality refers to any combination of virtual and real existence. MR has many options and can do more things than we think. Unlike

AR, in addition to adding digital projection to the actual physical environment, in MR we can also move with them, change, i.e. create inter-actions. With the help of added elements, we can make things that can be adapted to our needs and thus shape our own environment. In a sense, mixed reality is a more interactive type of augmented reality. As with VR and AR, in mixed reality to create an experience, there must be a MR device. It is either a submersible headset (Windows MR Headset) or a holographic headset that looks like translucent glasses (Microsoft HoloLensworks). More and more, this reality is also used in practical life. Mixed reality applications are expected to help companies with engineering and design modelling in sales and even with training and education of employees and others [14].

Reality - Virtuality Continuum

The concept of Reality Virtuality Continuum (RV) was first introduced to the world in 1994. The author who developed this understanding and perception of reality is Paul Milgram. In his scientific work “Augmented Reality: A class of displays on the reality-virtuality continuum” he argues that in order to define expanded and virtual reality, they should not be understood as two opposites, but it is more appropriate to place them in a two-ended region. So we are talking about a continuous scale with two extremes. Reality-Virtuality Continuum includes all possible compositions and variations of real and virtual objects because on the one hand a purely natural real environment is defined and at the other end of the imaginary scale there is only a virtual environment, otherwise called virtuality. Figure 2 shows what areas on the Milgram scale can be created by combining reality and virtuality. Between the real physical world and the synthetic digitally created world, we find an environment of mixed reality, which is understood as an environment in which the objects of the real and virtual world are presented within one display, i.e. anywhere between the extremes of the continuum. MR thus includes augmented reality (AR), where virtual content extends the real world, but also augmented virtuality (AV), where natural objects enrich the virtual world (Fig. 2). In the first case, we observe a physical environment with added enhancements generated by the computer. In contrast, in augmented virtuality, the surrounding environment is essentially virtual but is enriched with real (not computer-generated) image data [15, 16].

It is this concept that we want to use in our design. Connecting the real world tied to augmented virtuality. To apply augmented reality in practice, we need an appropriate device with which we can experience an expanded world. AR technology is an intelligent technology and can be classified into the following categories (Fig. 3):

- HEADS UP DISPLAY

Heads-up displays were developed mainly for the Air Force and were intended to make their work easier for pilots. They were used for complex applications, e.g. flight control devices, weapon systems. A conventional HUD has three main components: a projector unit, a sight glass (combiner) and a computer (content generator). Today, however, they are mainly used in automobiles as assistance, information or navigation systems. HMD is also related to the head-up display, which works on a static basis. The head mounted display is a device placed on the head and, unlike the HUD, moves at the same time as the head moves [18].

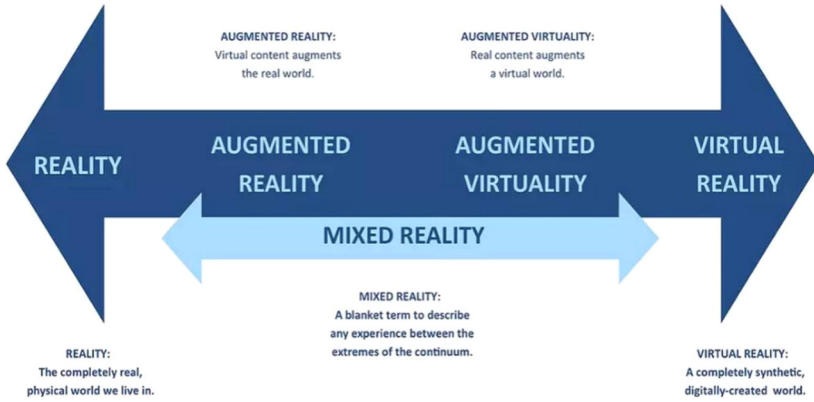


Fig. 2. Continuum reality-virtuality [authors own processing].

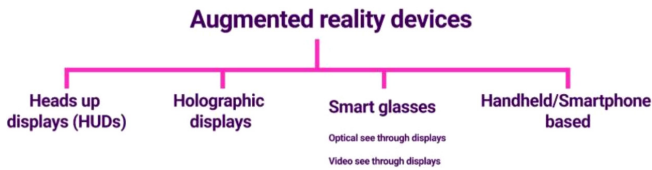


Fig. 3. Augmented reality devices scheme [16].

The holographic display shows a true 3D image easily, using a spatial light modulator. The holographic system uses a prism to connect light from the holographic display to the environment. They use light diffraction to create a three-dimensional form of an object in real space. Perhaps the biggest advantage of these displays is that they do not require any wearable device to see the AR. An example of this AR system is the Holovert device [17].

- SMART GLASSES

Recently, smart glasses are very popular in the company, which are on the market in two types. Video see-through and optical see-through glasses. HoloLens is one of the most popular devices of its kind on the market, manufactured by Microsoft. For their operation, they use many sensors and highly developed optics to add AR to the user environment. They also include several microphones, an HD camera, a light sensor and a holographic processing unit. Commands are executed by gesturing and moving the eyes. The second version of HoloLens 2 is currently on the market [19].

Magic Leap One is hardware that needs a wearable computer connected by a cable to futuristic design glasses to function. A controller with a large button and touchpad is used to control this device and interact with objects [20].

Google Glass Enterprise is a device used primarily for business. The employee activates and launches the necessary applications by voice commands. Also, these glasses

provide a live video stream where a person can collaborate and solve problems with other people [21].

There are many other similar intelligent AR hardware on the market, such as: Epson Moverio, Meta 2, Spectacles, DAQRI Smart Glasses, Atheer AiR Glasses, Vuzix M 300, Vuzix M 100, Monitorless, and others [22, 23].

- **HAND HELD DISPLAY**

Hand held displays are the most affordable and most widely used augmented reality devices. One apparatus contains all the necessary technologies needed for AR. We include smartphones, tablets and similar devices that have their operating system (iOS, Android). The Apple App Store is available for Apple's iPhone and iPad with iOS, where you can download many augmented reality applications. The Android OS is used by many manufacturers of smartphones and tablets (Samsung, Huawei, Honor, LG, Xiaomi). Like Apple, they have their store called Google Play Store with augmented reality apps. Easy-to-download applications we know are ARKit, ARCore, MRKit, the famous PokemonGo game and many more [18].

1.2 The RFID System

The basic principle of operation of RFID technology is that the antenna of the RFID reader generates an electromagnetic field which has a specific distance and shape of the range. RFID tag comes within range of the electromagnetic field, and its antenna receives the transmitted signal and induction in the antenna coil induces a voltage that serves as a power source for the RFID tag. The tag microprocessor processes the signal from the reader and makes available the information about the marked object contained in the EPC code [24].

The antenna of the powered RFID tag begins to transmit a signal which the reader detects and then sends the object information to the host computer system. My articles

As with many other types of automatic identification systems, an RFID system consists of several interconnected components. The basic RFID system consists of:

- RFID tag,
- RFID antenna,
- RFID reader,
- Middleware.

2 Work Methodology

As already mentioned in the introduction to the article, the issue of augmented reality is very extensive. In our proposed concept, we use the principle of Reality - Virtuality Continuum, which means using augmented reality and reading data directly in time using smart glasses. Therefore, we focused on the presentation of individual components that we will use in our design. We deal with two possibilities of implementing RFID measurements. One is the use of Smart glasses with a direct connection using a Bluetooth

RFID reader and reading RFID tags, and the other option is to connect to a local wifi network using Smart glasses and read the data from the RFID reader from the PLC output [25].

2.1 AR Components

The first component is the *SMART glasses Epson Moverio BT 350*. Its advantage is a low purchase price, but the problem area is that they work on the android system. Therefore, the software has to be adapted to this system. It can also be considered an advantage, as creating android applications is not complicated. The problem is that these glasses can only be operated with a control tracker that is connected with a cable [23].

The Epson Moverio BT 350 glasses have the following technical parameters:

- Processor: Intel® Cherry Trail Atom™ ×5 1.44 GHz Quad Core
- Display: Si-OLED with the resolution of 1270 × 720 pixels, stereoscopic
- Memory: 2 GB RAM, 16 GB storage + 32 GB microSD
- Camera: 5 Mpx
- Battery: 2,950 mAh Li-pol
- Connectivity: Bluetooth 4.1, Wi-Fi 802.11ac, GPS
- Operating system: Android 5.1.

The second component is the Microsoft HoloLens 2 SMART glasses. Microsoft created these on May 2, 2019. They work on Windows Holographics. Their advantage is that the glasses are autonomous, and their control is performed using hands and gestures. They contain two haptics sensors sensing the position of the hands (Fig. 4). The basic technical parameters are [26]:

- Processor: Qualcomm Snapdragon 850
- Display: See-through holographic lenses 2K 3:2
- Memory: 4-GB LPDDR4x system DRAM
- Camera: 8-MP stills, 1080p30 video
- Connectivity: Bluetooth 5, Wi-Fi: Wi-Fi 5 (802.11ac 2 × 2), GPS
- Operating system: Windows Holographic Operating System



Fig. 4. Smart glasses microsoft HoloLens2 and Epson Moverio BT 350 [authors own processing].

2.2 RFID Components

The principle of dividing components into hardware and software was used to design two RFID systems. The basis of the hardware part of the RFID system is an RFID tag, which contains unique information in a unique EPC code on the marked object. Another component is an RFID reader with an antenna, which is used to read the story and then forward it for processing via intelligent software. We use two types of readers in our systems. One is mobile, and the other is a static system with an RFID reader and antenna. The software also needs to be adapted for these readers. We will use RFID explorer software for the mobile reader and Simatic web Controller for the static one [27, 28].

RFID Tags

Confidex UHF RFID tags (Fig. 5) were chosen for the proposed systems. Their advantage is IP 68 resistance and readability up to 5 m (Table 1).



Fig. 5. RFID tags [authors own processing].


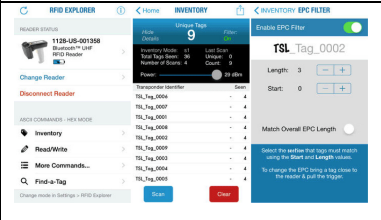
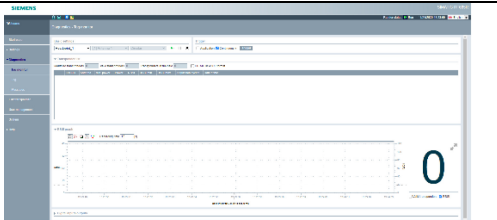

Table 1. Parametre RFID tagov Confidex [authors own processing].

Type	Dimension	Memory	Read range	Temperature	IP rating
Confidex IRONSIDE Micro	27 × 27 × 5,5 mm	128bit EPC + 512 bit (M4E)	Up to 5 m	−35 °C to 85 °C	IP68
Confidex SURVIVOR™	155 × 26 × 14,5 mm	128bit EPC + 512 bit (M4E)	Up to 18 m	−35 °C to 85 °C	IP68
Confidex Links NFC &UHF	50 × 7 5 × 0,2	HF:7BytesUID, UHF 128bit EPC	Up to 5 m	−35 °C to 85 °C	IP68

Reader

For the first concept, we will use the RFID reader TSL 1128 Bluetooth® UHF, which works with Smart glasses using Bluetooth. It sends the RFID tag data to the RFID explorer software, which processes it and sends it to the database. For the second concept, we will use a Siemens SIMATIC RF685R reader with a Simatic RF620A antenna connected to a PLC 1215C (Table 2).

Table 2. Mobile and static RFID system [authors own processing].

Mobile RFID system	Static RFID system
Reader	
TSL 1128 Bluetooth® UHF	Siemens SIMATIC RF685R including antenna SIMATIC RF620A
	
Software	
RFID Explorer	Simatic Web Controller
	
Smart Glasses	
Epson Moverio BT-350	Microsoft HoloLens2
	

3 Results and Discussion

Based on the research and application area, we can create one complex system or two smaller, mutually separate systems (Fig. 6).

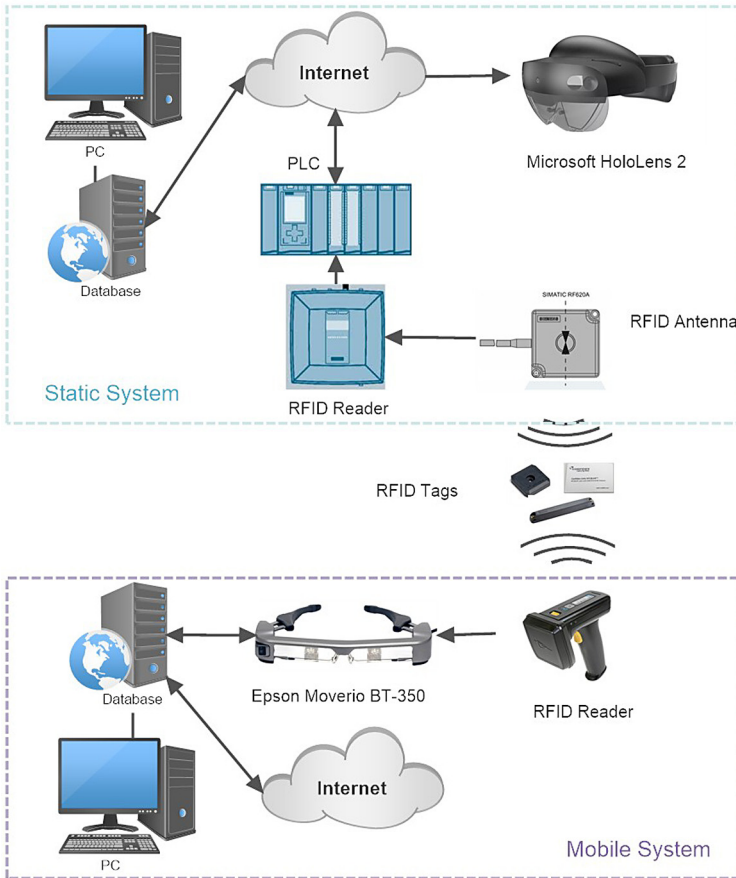


Fig. 6. Wiring diagram of mobile and static system [authors own processing].

3.1 Measurement Using a Mobile System

For this measurement, we used a TSL 1128 reader and information transfer using Epson Moverio BT-350 eyepieces. Their advantage is the simplicity of connection. For measuring and identifying the RFID tag with the EPC code, only glasses and a reading device are sufficient for us. The scanned data is transferred via wifi to a server that we set up in the program. The report export is created there. The view through the glasses and the working environment of the application shown through the remote access to the glasses is shown in Fig. 7.

The concept of a mobile reading system has its pros and cons, divided as follows:

Advantages:

- Simplicity - a system consisting of 2 components
- Mobility - allows loading anywhere in the business premises
- Low acquisition costs - the price of involvement is up to 2500 €

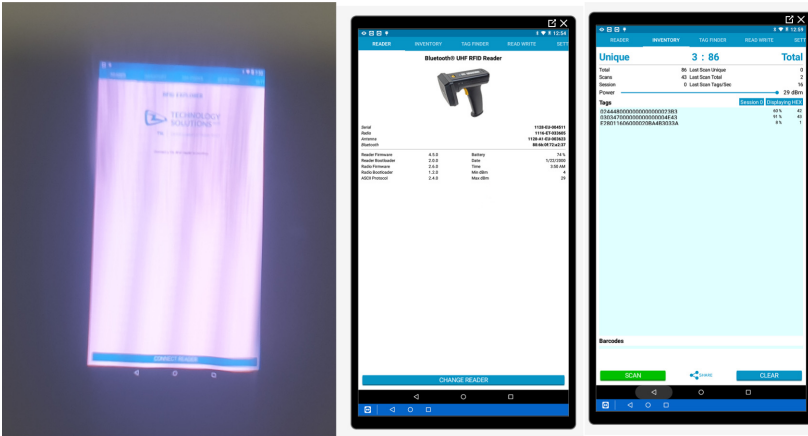


Fig. 7. Reading RFID tags using a mobile RFID system [authors own processing].

- Possibility to modify the application and outputs,
- Uploading data directly to the glasses or sending them to the database.

Disadvantages:

- Tracker control - there is no keyboard on the Smart glasses pointing device, and the glasses are controlled by a pointer
- Battery life - Smart glasses are not built for active connection of RFID reader via Bluetooth and online sending of data to the database via Wifi connection; this connection allows 1-h life.

3.2 Measurement Using a Static System

The connection of this system consists of the use of industrial components. First of all, it is a complex RFID solution in the relation of the tag-antenna-reader-PLC-display unit - wifi network. The researched workplace is the Laboratory of Lean Methods located at the Faculty of Manufacturing Technologies with a seat in Prešov of the Technical University of Košice.

In Figs. 8 and 9 we can see the individual components of the proposed static system. As shown in Fig. 9, the user has Smart glasses on and is connected to the local wifi network together with the PLC. The PLC processes all signals recorded from the reader or antenna. For simplicity and better reading, a connection to a gate mounted from an antenna and a reader between which the conveyor belt was located has been proposed. This made it possible to ensure multiple transitions of stored RFID tags between the gateway and to monitor the intensity of reading individual tags.

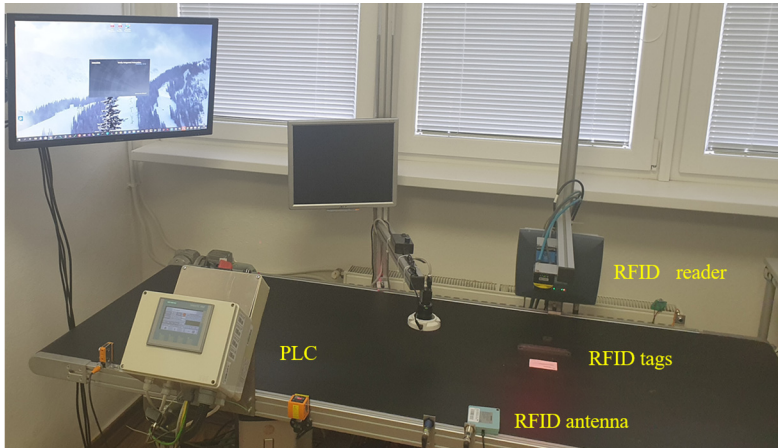


Fig. 8. The laboratory workplace [authors own processing].

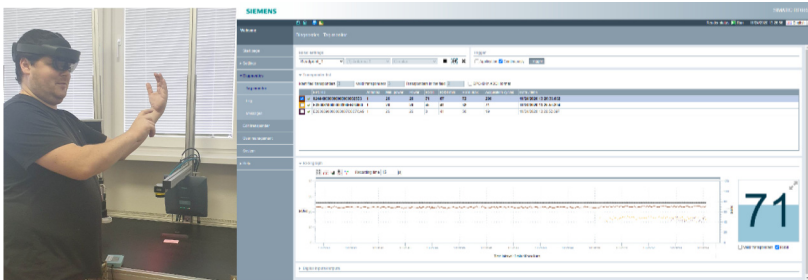


Fig. 9. Control of static RFID system and working environment [authors own processing].

The concept of a static reading system has its pros and cons, divided as follows:

Advantages:

- Accuracy of information - the created gateway allowed 100% reading of all tags.
- Battery life - Microsoft HoloLens 2 glasses with a connection to wifi and standard control have an experience of about 4 h. It means that the worker is not forced to charge the glasses frequently. After connecting the power bank, it is possible to extend the duration of use.
- Hand control - is intuitive, and within 2 min, the user can quickly see. He uses gestures and a virtual keyboard at work.
- Working environment - The glasses work on the Windows Holographic operating system, this environment is similar to ordinary Windows and therefore working with it is not complicated.

Disadvantages:

- High acquisition costs - the price of involvement in at least 10 000 €
- Gesture control - sometimes, there is unnecessary click-through using the wrong gesture.
- Problems with long-term use - after a long time of using glasses in augmented reality, you need to get used to the real world.

4 Conclusion

In the presented paper, we focused on the possibilities of using Augmented reality, esp. smart glasses as a tool for performing RFID measurements. The article has designed for two systems. The first is a mobile system, and its crucial advantage is that it can identify UHF RFID tags in space, and the user can move around the production without restriction. The reader is cheap and easy to use. The second system is static. Its disadvantage is that it has a fixed reading area, which means that the user can read the scanned data anywhere and in any amount. It is sufficient to connect to a common local network. The main goal of the article is to remove standard display devices from production and replace them with smart glasses, which we confirmed on two concepts in this article.

The idea and further direction of the research team in the future are to optimize the hardware and software side for commercial purposes of manufacturing companies and to put the knowledge acquired so far into practice.

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