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Original Research

USE OF AUGMENTED REALITY FOR SMALL PARTS ASSISTED ASSEMBLY

WYKORZYSTANIE RZECZYWISTOŚCI ROZSZERZONEJ DO WSPOMAGANIA MONTAŻU MAŁYCH CZĘŚCI

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Abstract

The use of augmented reality (AR) for assisted assembly of small parts remains a current and dynamically developing issue in industry and the technology sector. Because AR technologies and related applications are constantly advancing, it is necessary to pay sufficient attention to this topic. This article provides a simplified view of software application design and architecture. We are focusing on a 45mm x 45mm x 42mm component consisting of 42 parts. In the article, we gradually show how to properly create an application with a main, and working environment in which we can create animations from a database of 3D models. In the end, we performed a product assembly test with and without the use of the AR application, for one piece and a production batch. In conclusion, we can state that the applications have an impact on the training of the workforce and the ways through which new workers are prepared to work in an industrial environment. Improved education and training programs based on AR can help integrate new workers into production processes faster and more efficiently. Considering these perspectives and the dynamics of the AR technologies development, our article raises awareness of current trends and innovations in this field, as it can have a significant impact on the efficiency and competitiveness of various industries.

Keywords: AR application, assisted assembly, Unity, architecture of application

Streszczenie

Wykorzystanie rzeczywistości rozszerzonej (AR) do wspomaganego montażu małych części pozostaje aktualnym i dynamicznie rozwijającym się zagadnieniem w przemyśle i sektorze technologicznym. Ponieważ technologie AR i związane z nimi zastosowania stale się rozwijają, należy poświęcić temu zagadnieniu odpowiednią uwagę. W tym artykule przedstawiono uproszczony pogląd na projektowanie i architekturę aplikacji. Skupiamy się na komponencie o wymiarach 45 mm x 45 mm x 42 mm składającym się z 42 części. W artykule stopniowo pokazujemy jak poprawnie stworzyć aplikację zawierającą środowisko główne oraz środowisko pracy w którym możemy tworzyć animacje z bazy modeli 3D. Na koniec wykonaliśmy test montażu produktu z aplikacją AR i bez niej, dla jednej sztuki i partii produkcyjnej. Podsumowując, można stwierdzić, że aplikacje mają wpływ na szkolenie siły roboczej i sposoby przygotowania nowych pracowników do pracy w środowisku przemysłowym. Ulepszone programy edukacyjne i szkoleniowe oparte na AR mogą pomóc w szybszej i skuteczniejszej integracji nowych pracowników z procesami produkcyjnymi. Mając na uwadze te perspektywy oraz dynamikę rozwoju technologii AR, nasz artykuł podnosi świadomość aktualnych trendów i innowacji w tej dziedzinie, gdyż może to mieć istotny wpływ na efektywność i konkurencyjność różnych branż.

Słowa kluczowe: Aplikacja AR, montaż wspomagany, Unity, architektura aplikacji)

1. Introduction

Augmented reality (AR) represents an innovative approach that affects many industries, with one area with great potential being the production and assembly of small parts. Assembly of these small components is often a difficult task that requires high precision and expertise of the operators. However, with the AR technology development, new possibilities are opening up to improve this process. This article will focus on the use of augmented reality for the assisted assembly of small parts and explore how AR can increase the efficiency, accuracy and quality of production in this specific industry Kaščak (2019).

Currently, 11.5 million people in the U.S. work in assembly departments, representing 8.8% of the workforce, and this number continues to grow. Global assembly is projected to face a shortfall of 7.9 million workers by 2030, resulting in an unrealized economic impact of $607.1 billion if current initiatives do not change. Brazil is projected to need 1.7 million assembly workers by 2030, while Indonesia could face a labor shortage of 1.6 million. The United States is already struggling with a shortage of high-skilled manufacturing workers, and this shortage is expected to increase significantly over the next decade, reaching 383,000 by 2030, the equivalent of more than 10% of the high-skilled workforce. As a result, of the effort to eliminate the shortage of qualified personnel, the manufacturing industry, which has traditionally developed rather slowly, is rapidly moving to integrate AR technologies. Global AR/VR spending will reach $160 billion by 2023, up significantly from $16.8 billion in 2019, and AR/VR spending could grow at a cumulative annual growth in spending of 78.3% over the five years. Commercial uses of these technologies, which are expected to see the largest investment in 2023, include training ($8.5 billion) and maintenance ($4.3 billion) Pettyjohn (2023). With the increasing number of businesses adopting AR/VR technologies for various use cases, the AR/VR market is expected to grow. These technologies will play a key role in expanding human resources. Current advances in hardware and software—initiatives and efforts by tech giants such as Google (ARCore), Apple (ARKit 3), and Microsoft (HoloLens)—will open up more opportunities and push AR/VR toward widespread adoption. Hardware will account for more than half of all AR/VR spending. Spending on system integration services will grow at the highest rate (94.8% annually), overtaking consulting services and application development, while software costs will grow by 70% annually. Strong growth in spending on AR hardware, software and services (135.5% per year) will lead to a significant overshoot in total AR spending by the end of 2023. The rise of AR/VR use in enterprises will be a direct result of the increase in production volume as companies implement new technologies to increase productivity, safety and achieve high accuracy. Interest in AR continues to grow exponentially. Now it's also powered by artificial intelligence, which allows cameras to "understand" the world and overlay digital content on top of it. Combined with ever more powerful and lighter devices, the coming years will be crucial for augmented reality development Poetker (2019).

1.1. AR and assisted assembly

The use of Augmented Reality (AR) for small parts assisted assembly is a promising and innovative field that has the potential to fundamentally impact various industries, especially manufacturing and service. With AR technologies development the door opens for new ways to increase the efficiency, accuracy and quality of the small components assembly Radianty (2020).

One of the significant ways how AR positively impacted assembly is providing assembly guidance for production and service operators in real-time. With the help of AR glasses or mobile applications, operators can get interactive 3D models, animations, instructions and procedures right at their workplace. In this way, the need for traditional written instructions is minimized and operators are able to assemble parts more accurately and efficiently Antosz (2019).

In addition, AR enables visual inspection of product quality during assembly. Operators can use AR to display the optimal image of the product and compare it with the real product to detect possible errors or flaws in the assembly. In this way, product quality increases, and the risk of errors is minimized Gatial (2023).

Interactive assembly tools and virtual assembly of parts are other important aspects of the use of AR in small parts assembly. Operators can create a virtual environment where they can store and examine individual components before actual assembly. This makes it possible to detect potential problems or conflicts between components before assembly begins.

In addition to these direct benefits of AR, this technology also offers effective solutions for the education and training of new assembly workers. Simulated assembly training in an augmented reality environment reduces the time needed to acquire skills and experience, thus contributing to a faster and more efficient introduction of new workers into production Heinzel (2017).

AR also has the potential to recognize and track parts throughout the manufacturing process, improving inventory monitoring and optimizing processes. Improved communication between operators and technical support or other manufacturing departments is another benefit that AR brings through the ability to share insight and information in real time.

All in all, the use of augmented reality in the small parts assembly promises to revolutionize the industrial environment. With the help of this technology, it is possible to increase the efficiency of assembly, improve products quality, save costs for training workers, and increase communication within the production processes, thereby contributing to competitiveness and innovation in industries Kaščak (2022).

1.2. Literature review

The papers collectively suggest that augmented reality (AR) can be used to assist in the assembly of small parts Okamoto Jr. (2016) proposes an AR system that recognizes parts and guides users through the assembly process using virtual graphic signs. Dupláková (2021) describes the use of AR in the assembly process to speed up and facilitate assembly while preventing errors. Ojer (2020) presents a projection-based AR system for assisting operators during electronic component assembly processes. Ceruti (2017) proposes an innovative methodology using virtual and augmented reality to support assembly, including the development of a knowledge-based system and the production of a virtual user manual. These papers collectively demonstrate the potential of AR for assisted small parts assembly.

This article focuses on an augmented reality application for assisted assembly that allows technicians and assembly workers to streamline their work and minimize assembly errors. It uses augmented reality to display 3D models and other visual information directly on physical objects in real time. In this way, the technician can visualize how the device or part of it should look after assembly and what are the optimal steps that should be taken during assembly Milgram (1995).

The application may also contain step-by-step instructions and other assembly information. In this way, technicians and assemblers gain confidence in the assembly and can assemble faster and more efficiently, reducing the cost and time required to carry out the assembly. The application thus helps to increase productivity and improve assembly quality Luo (2018).

2. Methodology

As can be seen from the analysis so far, the main goal is to focus on a specific product consisting of a number of small parts. For our purposes, we chose a cam switch. It consists of 42 parts, of which 23 parts are different assembled in a 45mm x 45mm x 42mm cube. Currently, the cam switch assembly is carried out manually during the entire process in production, based on the technological procedure indicated in paper form.

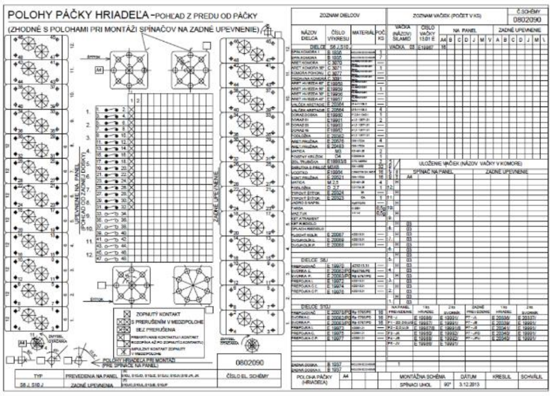

Fig. 1. Production drawing with technical specification

The picture below shows the final product and the switch in its disassembled state.

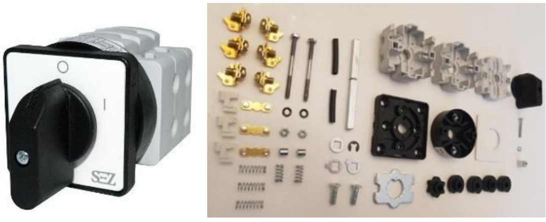

Fig. 2. Cam switch

The total assembly consists of 5 steps:

1. Description
2. Manual assembly
3. Testing
4. Visual inspection
5. Packaging

The total assembly process of 1 piece of cam switch takes 3 minutes 50 seconds, and 20% of the total time is assumed for the permitted deviation. According to the assigned order, the employee will receive a manual in which the adjustment of the lever positions for the main shaft, for a specific type.

Fig. 3. Current assembly workplace

As can be seen from Fig. 3, the manual assembly workplace consists of a work table, boxes with components, preparations for assembly and a technical manual (Fig. 1). The basic production procedure does not change, but the designs change due to the switch closing requirement and according to the type Kovbasiuk (2023).

2.1. AR application creating process

The first thing to do when creating an application is to build a CAD model of the assembled part, consisting of all components. For the application requirements, we created a model in Autodesk Inventor and then saved each component as a separate model in *.obj format. We used 26 models to create the database and animations.

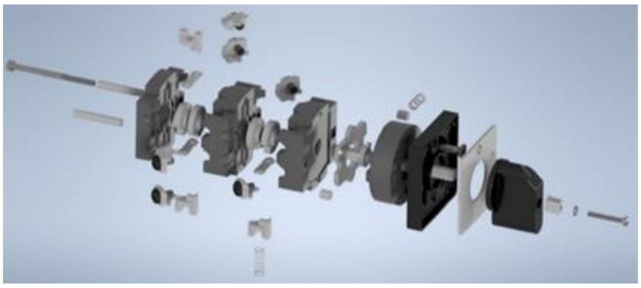

Fig. 4. 3D cam switch model

These 3D models need to be imported into the Unity development tool in which the AR application will be created. At the beginning, we need to create a basic manual of how the application will look. What will be its structure, what will it contain, how many layers will it consist of and what online/offline interactions should it offer. We can say that we will create a simplified architecture of the assembly application.

The architecture of an augmented reality (AR) application depends on many factors, including the purpose of the application, the target platform, and the type of device that will be used to display the AR content. In general, an AR application should include these basic elements:

- Sensors and devices: An AR application should use sensors and devices to capture input data, such as cameras, motion sensors, and ambient sensors.
- Data processing: The data captured by the sensors should be processed and analyzed to find out where the user is, where he is looking and what he is doing.
- Visualization: The AR application should be able to display AR content on the device display so that it appears as part of the real environment. This process involves combining AR content with surrounding objects and adjusting perspective, lighting and other factors.
- Interaction: The user should be able to interact with the AR content, for example by hand movement or voice command. The application should be able to record these interactions and adapt to them.
- Synchronization: The application should be able to synchronize AR content with other devices and applications within the network to share experiences among users.

Considering the complexity of these requirements, it is advisable to have a high-quality architecture in the AR application, which will enable simple and effective data processing, visualization, and interaction with them. It is also important to choose the right platform and device that will be used to display AR content and ensure their optimal functioning.

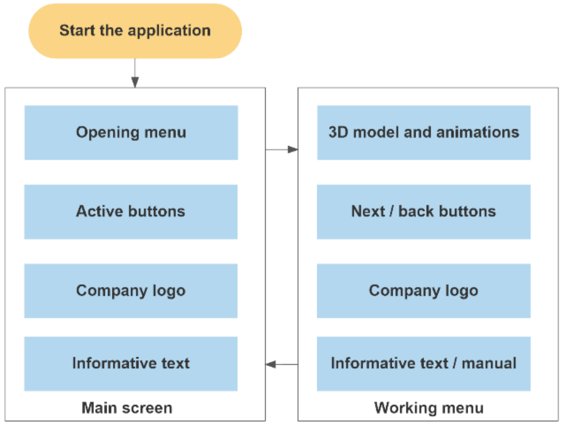

Fig. 5. AR application architecture

The presented AR application was created in the Slovak language modification, as it was solved based on the specific requirements of the company. As a first step in the Unity environment, we will define the appearance of the initial main menu in which we will set the main links. We achieve this by creating user buttons through the User Interface, where we define the button's shape and their interaction. The click is felt when in contact with the display surface or in the ARCamera interface.

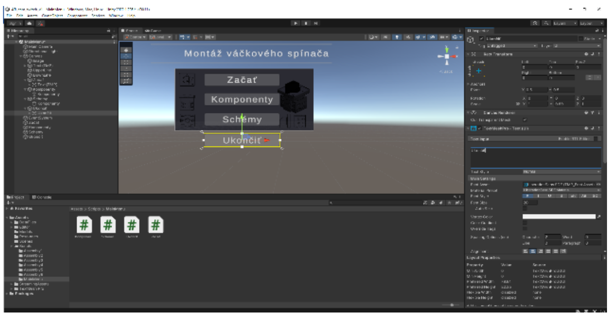

Fig. 6. Main Menu in Unity software

After defining the buttons area, the creation of User Interface links with the help of scripts to the main scenes takes place.

Script to run the application.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.SceneManagement;

public class Zacat : MonoBehaviour
{
    public void StartGame()
    {
        SceneManager.LoadScene("Assembly1");
    }
}
```

After clicking on the selected button, a script will run that will connect us to the scene of the first assembly process (Fig.7). First, we will set up the display of the working menu of the application. This consists of informational text for the individual actions of the "Ďalej", "Späť", "Home Icon" and "Refresh Icon" buttons. In addition to the main camera during assembly operations, it is also necessary to create an ARcamera interface. With this setting, we chose the technical drawing of the cam switch as the basic working marker. The marker is imported into the Vuforia Developer portal database and interacts with the application being created via a unique license key. Markers can be changed according to the library of created models.

Fig. 7. Work Menu in Unity software

To create an animation of the first assembly operation from inserting 2 screws into the locking chamber, open the Animator Controler and define the assembly process operation: moving the screw along the Z coordinate to the green area.

After performing the operation, we will use the "Ďalej" button, which will start the script and link to the "Assembly2" scene - Assembly operation 2. It will place the arresting chamber on the rear attachment.

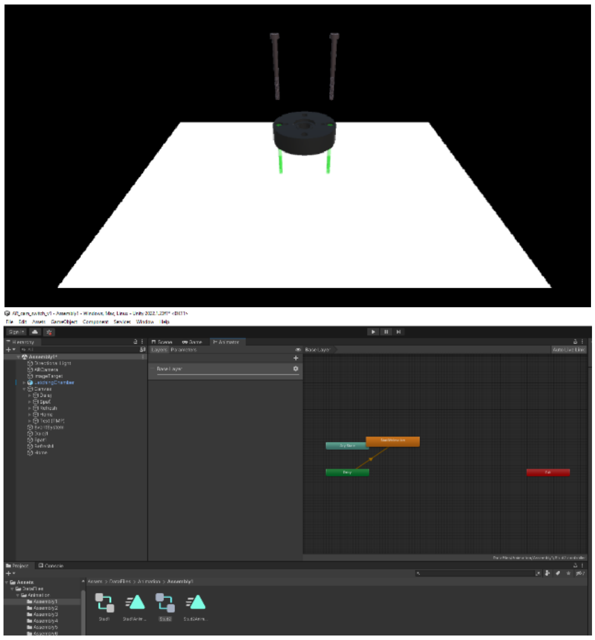

Fig. 8. Setting the animation scene

To create scenes in the application, we will use the models database from the library. Since it is a "*.obj" format, i.e. j. colorless model, it is necessary to define a texture for each depicted element. We create individual textures from the "assets" database or upload them as our own color.

Fig. 9. Library of 3D models and materials

By repeating these procedures and working with an animator, we will create a complex application consisting of 26 scenes with 35 animations defined in the technological assembly procedure.

3. Results

The application is universal from the point of view of the main and working menus. What will change during individual assembly operations is the view of ARCamera, the description of the operation and the animation loaded from the database. The application created in this way represents a universal tool that can be implemented in industrial conditions.

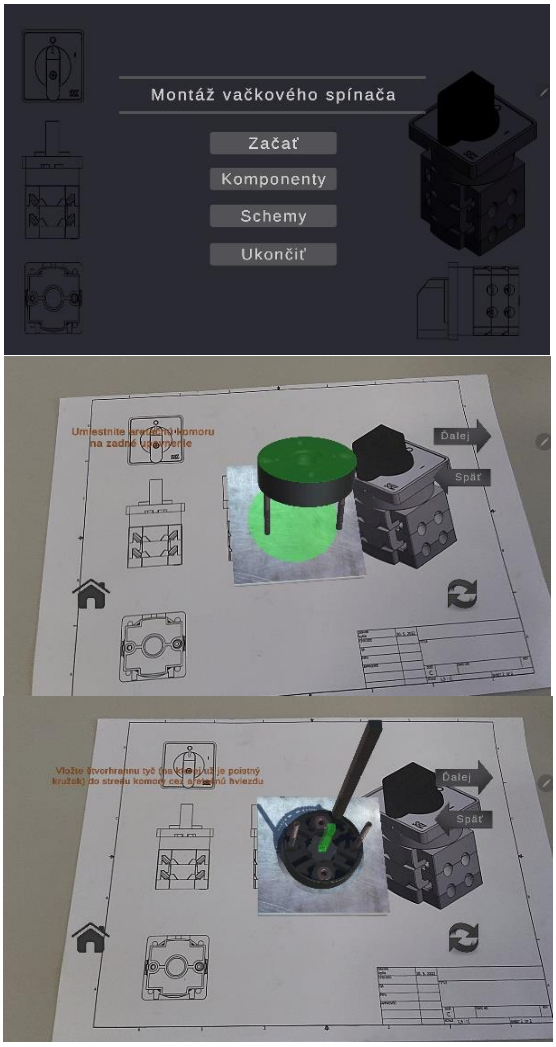

Fig. 10. Screenshots of the AR app for assisted assembly

The interesting thing about the proposed application is that we use a technical drawing as a marker (area for depicting the application), but the design allows us to use specific text or a QR code as a marker. This opens the possibility of printing an order form containing the QR codes of the products, and after scanning the code, a specific product is selected and the required application is launched online.

To verify our application, we measured the assembly time without and with the AR application for 1 piece and 10 pieces. The results can be seen in Table 1.

Table 1. Assembly time measurement with and without AR application

	Assembly time for 1 piece (s)	Assembly time for 10 pieces (s)
Without AR application	230	2053
With AR application	197	1668

The application created by us reduced the assembly time for one piece from 230 seconds to 197 seconds, which represents a 14.3% reduction in time. After 10 repetitions, the assembler's independent learning was also recorded and the expected time of 2300 seconds did not occur but was shortened to 2053 seconds. If we performed repeated measurements using the AR application, we arrived at a reduction in time to 1668 seconds for 10 pieces, which represents a reduction of 18.75%.

Overall, we can conclude that the use of AR applications during assembly accelerates the learning of employees, reduces the rate of errors and supports their intuitiveness.

4. Conclusion

Our proposal of assembly application interaction in augmented reality can bring great benefits to assisted assembly. Some of the main benefits of combining these technologies are mainly:

- Improve accuracy and efficiency: Creating an augmented reality application allows workers to see in real time a virtual version of the product they are working on and compare it to the physical version. This can help improve accuracy and work efficiency.
- Minimizing errors: The application allows us to create a virtual version of the product and test its functionality and assembly before actual assembly in the real world. Linking a real-world model with an augmented reality application allows workers to see virtual elements and compare them with physical ones, which can minimize the risk of errors.
- Increased safety: Linking an augmented reality application with a real-world model can help increase safety at work by allowing workers to see virtual elements and instructions in real time, which could help minimize the risk of errors and accidents.
- Cost reduction: Creating a product virtual version and testing its functionality and assembly before actual assembly in the real world can help minimize the cost and time needed to correct errors.
- Increase productivity: Linking an augmented reality application to a product can help increase worker productivity by allowing them to see virtual elements and instructions in real time, minimizing time spent searching for the right tools and components.

Overall, connecting an augmented reality application with a real product can bring several benefits to assisted assembly, improving accuracy, efficiency, and work safety, and reducing the cost and time needed to correct errors. In the future, the author's collective plans to solve the creation of an online simplified AR application architecture, which will be connected to the database and cloud storage. The client connects to the application, creates a user interface and then just loads 3D models and assembly processes with timing from the cloud. Such a concept represents a solution that can be modified for various companies and is widely used in practice.

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