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AUGMENTED REALITY ASSISTIVE APPLICATION FOR FURNITURE ASSEMBLY

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Abstract – *The level of automation in Vietnamese industries is low. In furniture manufacturing, one of the strongest industries in Vietnam, the human workforce is still one of the most essential factors in production. In the furniture assembly process, the correct and effective assembly is a crucial requirement for both operators at the workplace and the customers at home. One of the main problems frequently occurring in manual assembly is errors due to a lack of clear instructions. Augmented reality has the potential to solve this problem. Existing approaches hardly regard home assembly and highly flexible layouts in production. This research focuses on immersing augmented reality in furniture assembly. In this paper, a concept for augmented reality for commercially available mobile devices is designed to provide visual guidance in the assembly. The augmented reality prototype shows a high potential for increasing productivity in the furniture industry.*

Keywords: assistive application, augmented reality, automation, customer experience, furniture industry.

I. INTRODUCTION

The level of automation in Vietnamese industries is low. In the furniture field, one of the strongest industries in Vietnam, the human workforce is still one of the most essential factors in this industrial production. Most of these employed workforces are currently engaged in the manufacturing sector process for manual assembly. The operator proves to be important to the assembly process due to their cognitive skills and flexibility. However, besides human operator's advantages, human errors in the assembly process inevitably raise the manufacturing time, costs, and wastes, and even downgrade the quality of the product [1]. Many methodologies have been implemented to reduce human error in the assembly process, such as personnel training (including on-the-job training, face-to-face training, and computer-based training), design for Poka-Yoke assembly, sensors to identify potential errors, and 3D CAD models that provide a detailed graphical view of the product [1]. Among those methodologies, augmented reality (AR) has been proven to be a potential assistive solution to human error [2–4].

In addition, in the furniture industry, the delivery section also faces several challenges. Some furniture is heavy and wide, and a highly unassembled product like a sofa is easier to deliver in separate parts than transferring the whole item. Most furniture products such as sofas, couches, beds, etc. are always in a giant-scale final form. Often, before delivery, they are disassembled and contained in several packages along with tools and guideline instructions. The main reason is to make it more portable [5–7]. AR assistive applications can be used as an instruction to support the manual assembly process for both operators at the workstation and customers at home. An AR application can help to indicate the required manual assembly processes. Visual representations of temporarily registered components on the screen illustrate, where the physical components should be assembled [8]. Hence, by integrating visual representations into

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the real working environment, AR can allow operators as well as high-end customers to achieve the correct assembly process increasing accuracy and avoiding errors [9].

However, the use of AR is currently in an experimental phase. There is still a high potential for new applications and developments in AR [1]. This research paper describes an AR assistive application for guiding furniture assembly processes. The application is prototypically developed for commercially available mobile devices, which can support the delivery and assembly phase of the furniture industry faster and more convenient in tracking the assembly process. This point is a promising factor in reducing labor effort and time for the industry sector.

II. STATE OF THE ART

In recent years, AR technology has been applied in numerous fields for different purposes. Its implementations have been introduced and developed for various fields such as education, gaming, medicine, navigation, and tourism [10, 11]. AR technology is regarded as a type of interaction between humans and computers that superimposes visual-based information in the real-world environment [12]. These two kinds of information are mixed and overlap with each other to emphasize the augmented perception of users. There exist numerous types of hardware for displaying visual interfaces, such as LCDs, hand-held screens, in-situ projection, and head-mounted displays (HMD). In visual augmented reality, users use HMD to have a fully immersive experience with the computer graphics with the real world around them [13]. With a high level of AR technology, AR assistive applications can introduce users to assembling processes more effectively. By showing them how the assembly process works to reduce the time required for assembly while maintaining the high quality of the products [14]. Many industries such as electronics, automotive, aerospace, and furniture have applied different concepts of AR assistive application for the assembly process. The application of AR for assembling printed circuit boards (PCB) is proposed by Hahn et al. [15]. In that paper, they introduced an AR assistive application for giving instructions to the assembly process of PCB for operators by using self-developed software running on AR glasses. QR codes (markers) are implemented in the system to trigger visual representations. Four markers are used to highlight the location of the installation point within the user's field of vision. The authors could show the feasibility of this application. Nevertheless, they encountered several usability issues due to using highly deteriorated vision AR glasses [15]. Westerfield et al. [16] introduced an AR assistive application to the motherboard assembly. Their application indicates the combination of AR graphics with adaptive guidance from intelligent tutoring systems to assist with training for the manual assembly process. A prototype was built to teach novice users how to assemble a computer motherboard. The results show that AR assistive application improved 25% test score and 30% faster compared with traditional AR training. The feasibility of this application could be applied in other assembly or maintenance tasks. However, this application is hardly convenient for use at home. AR glasses have to be connected to a computer. The application has not yet been applied in a manufacturing environment. Mendivil et al. presented an AR assistive application in the automotive industry to guide the user through the assembly or disassembly of a car engine [17]. This paper describes how entrepreneurs explore new technologies that simulate and texturize related parts as instructional mini-animations, matrix markers, and In-Situ projection to develop an AR system for assembling a monobloc engine. The feasibility of this application could be generated in different fields. However, this technology would not be easy for the low experienced user using it without training.

In the aerospace industry, Serván et al. [18] investigated the execution of the MOON project (asseMbly Oriented authOring augmeNted reality), developed in 2010. The MOON project dedicated the key role of industrial Digital MockUp

Table 1: Comparison of approaches

No.	Characteristic of furniture industry	Existing approaches from literature					
		Industry	Automotive	PCB	Aerospace	Motherboard	Furniture
		Source	Mendivil, E. G., et al [11]	Hahn, J. et al [9]	Servan, J. et al. [12]	Westerfield G., et al [10]	Hartanto H. et al [3]
		Techniques	Simulated and texturized related parts as the instructional mini-animations, markers matrix, in-situ projection	QR-Codes that activate their respective modes based on their content once they are viewed with the system	iDMU, Markerless camera pose estimation, 3D Processing Subsystem	Motherboard Assembly Tutor (MAT), Intelligent Tutoring System (ITS)	Android platform, AR system on mobile devices
1	Home-assembly		○	○	○	○	●
2	Assembly with screw, rivet,..		●	○	○	●	●
3	Easy when using AR		◗	◗	○	◗	●
4	Highly flexible layout in production		●	●	○	◗	○
	Symbols:	●	Fully achieved	◗	Partly achieved	○	Not achieved

(iDMU). In the paper, by demonstrating the concept of iDMU, the implementation of AR assistive application on the shop floor for the assembly process is described. The result was that AR assistive applications could be an alternative solution to conventional paper instruction. Nevertheless, it requires a high level of AR technology for the aerospace industry due to its complex assembly process. Specifically, in the furniture industry, Eswaran et al. [4] introduced AR assistive applications along with mobile devices to enhance visual guidance and assist non-experts. A mobile application called Arsembly has been developed. Arsembly runs on an Android platform to flexibly operate through customer's smartphones. 96% of customers were satisfied and agreed that they learn assembly processes better from Arsembly than from manuals. However, the scope of Arsembly is just for home assembly, it has not yet been applied for assembling furniture at a workstation where flexible abilities are required. In addition, Arsembly remained an unstable figure and had a slow and lagged scanning process. The unstable figure results from the level of sensitivity in the marker.

The strategy for producing furniture is 'make to order'. Hence, the characteristics of the furniture assembly in the production are highly flexible layouts. This means this assembly process currently produces product A, and a couple of minutes later, the product is changed to type B for production during this assembly process. Many products only have a minor difference but their assembly process is not the same. It requires easy methods for changing the product in a few minutes together with high accuracy in changing the product. In addition, assembly with screws, rivets, and home assembly also are typical features of the furniture industry. Table 1 shows current applications of AR are evaluated concerning characteristics in the furniture industry.

The current approaches do not fully fulfil the requirements such as home-assembly and highly flexible layout in production (see Table 1). To achieve all of the requirements mentioned, several advantages of current approaches are used to build an AR-assistive application available on mobile devices. However, they cannot achieve all requirements at the same time. Considering the cases expressed by Syberfeldt et al. [9], Abutaleb et al. [10], Huang et al. [11], and Nee et al. [12], they do not support mobile devices but enable home assembly as described in the study conducted by Mukul et al. [3] does. In another case, Mukul et al.'s research [3] supports mobile apps but lacks a highly flexible production layout. To overcome those gaps, this study deploys the mobile technology Mukul et al. [3] used to improve upon the limitations found in previous works [9–12]. Additionally, product details linked to QR codes are incorporated to enhance the accuracy of the assembly process. Moreover, the simulated and texturized related parts are demonstrated as instructional mini-animations, which help operators and customers easily assemble products to overcome the missing, which Mukul et al. [3] cannot achieve.

III. CONCEPT OVERVIEW

This section demonstrates the concept of usage for the operators and the customers along with the functions of the AR assistive application.

A. Usage concept of AR assistive application

This AR assistive application would follow logical sequence flowcharts described in Figure 1 for both operators at the workstation and the home-assembly customers.

At the workstation, when receiving a changing-over signal, the operators will change the layout of the assembly process. Different materials may also be required. The operators will put the label's QR codes into the camera's vision mounted on the workstation. QR codes will trigger the visual representation of the furniture shown on the LCD. This LCD is integrated with a minicomputer, which has already been installed in the AR assistive application. Operators observe the LCD and follow the instructions of the AR assistive application. After receiving and unpacking the furniture, home-assembly customers can get their mobile devices to download the free AR assistive application onto the store. Customers open the app and scan the QR codes on the product label by following the instructions of the AR assistive application to assemble the product.

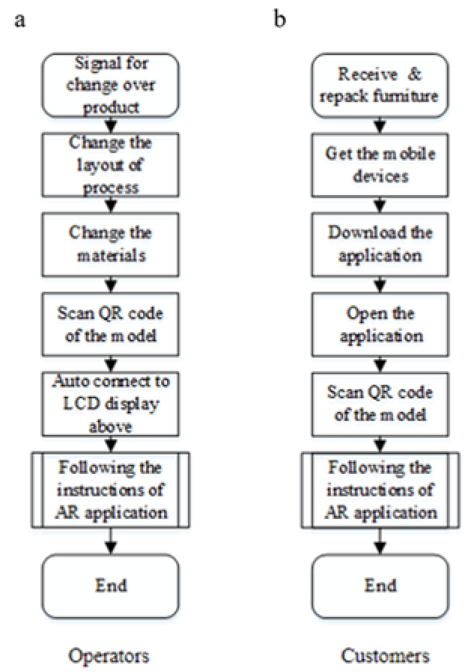

Fig. 1: Usage concept for operators (a) and customers (b)

B. Function concept of AR assistive application

Figure 2 demonstrates the function concept of the AR assistive application. When interacting with this AR assistive application's user interface (UI), users can first have a general view of an unassembled visual chair to imagine the required assembly steps. The final form of a fully assembled chair will be displayed later on the AR application so that users can check if they have done it correctly or not. Besides, the users can also adjust the size of the visual chair for better vision.

IV. IMPLEMENTATION

A. Development concept of AR assistive application

Figure 3 illustrates the development concept of our AR assistive application. The 3D models are created by using NX Siemens software. The NX files later on are converted into a Unity environment. The Unity engine and Vuforia coding processes support the implementation of the

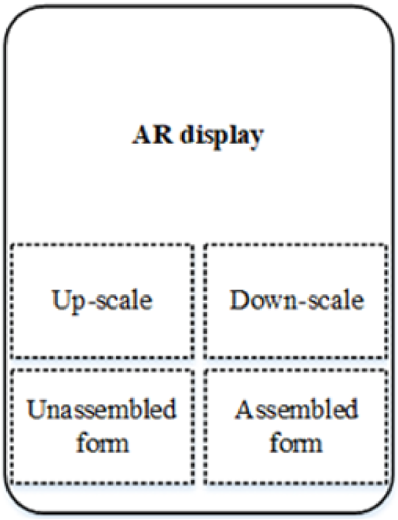

Fig. 2: User Interface concept

AR visual representation. Finally, the AR visual representation is exported into an application to be installed on the LCD at the workstation or on mobile devices

Fig. 3: CAD model of a chair in Unity environment

B. Required tools

NX Siemens: According to Siemen company, Siemen NX software is a flexible and powerful integrated solution that helps designers deliver better products faster and more efficiently. Users can create engineering drawings from 3D models by using efficient drafting tools.

Unity: According to Unity company, Unity is a game engine developed by Unity Technologies that provides the required tools for users to develop games. Users can enhance their CAD models with various visual effects including 2D/3D graphics, textures, shading, etc. Programming languages like C# and JavaScript are supported for the scripting process.

Vuforia: According to Vuforia company, Vuforia is regarded as a software development kit (SDK) for AR development. It provides the marker-functionalities of target tracking and recognition. The user can import the desired image target to define the trackable marker for marker-based AR, which will trigger the visual representation of objects.

C. Creating the CAD model

To create the CAD model of a chair as in Figure 4, NX Siemen software is used. Figure 4 illustrates the CAD model of a chair designed in the NX environment.

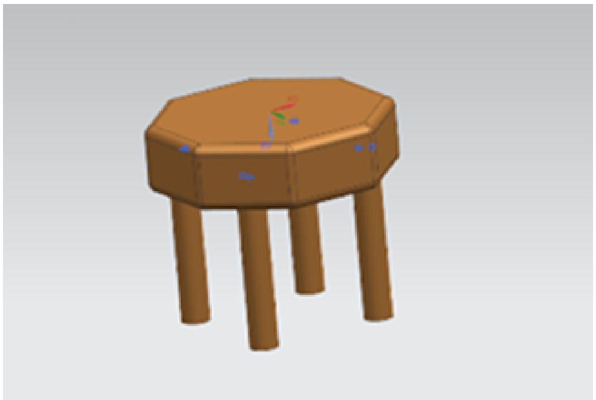

Fig. 4: CAD model of a chair

After the modeling has been completed, an AR assembly scene in Unity can be generated by importing the CAD model of a chair into the Unity environment. Usually, these importing actions can be done through the 'importing assert' panel provided by Unity. However, in this case, Unity does not support NX files. The Pixyz plugin is used for converting NX files into Unity environments. After importing, the CAD model of a chair is allocated within the Unity environment. This CAD model is a game object registered on the left-side hierarchy column (see Figure 5).

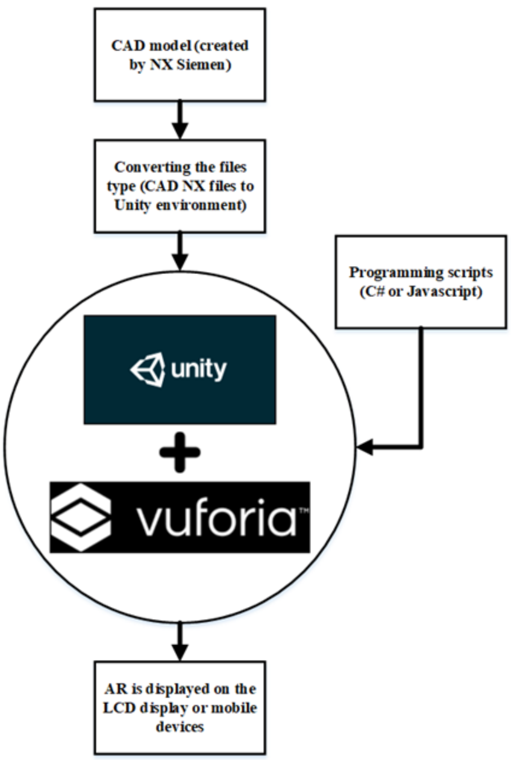

Fig. 5: Development concept

D. AR recognition and tracking

The QR codes used as 'ImageTarget' markers are registered on the Vuforia. By activating the 'Arcamera' and 'ImageTarget' on the Hierarchy column, the coordinates X, Y, and Z of the 'Arcamera' and the 'ImageTarget' can be adjusted to achieve a complete view of the visual chair. Four visual buttons including 'Up-scale', 'Down-scale', 'Unassembled form', and 'Assembled form' are created and adjusted within the 'Arcamera' view. The specific functionalities of these buttons are added by coding strips (Figure 6).

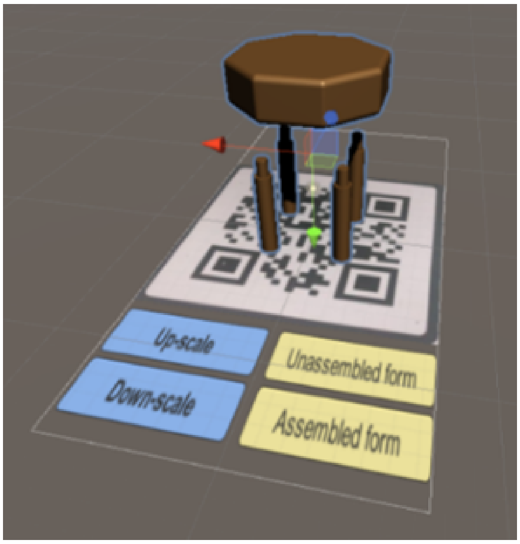

Fig. 6: CAD model of a chair in Unity environment

E. AR result

For customers at home, the visual representation of the chair and four buttons can appear on the display of their mobile devices while the camera captures the QR codes, as shown in Figure 7. As for the assembly process at the workstation, a proposed assembly process was conducted in a practical furniture company with the following components shown in Figure 8.

Fig. 7: AR assistive application is opened on mobile devices

Workplace: Assembly work-in-progress (WIP) and assembly tools are on the table.

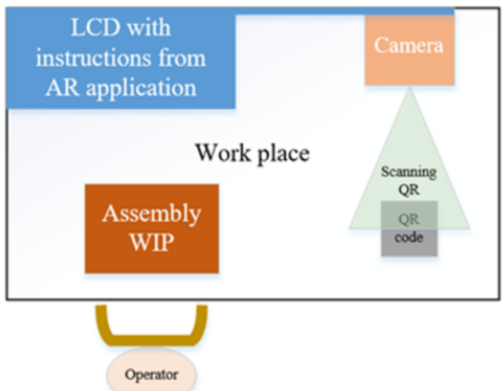

Fig. 8: AR assistive application is opened on mobile devices

LCD was held on a frame to show the instructions from the AR assistive application.

The camera was held on a frame to scan the QR codes. Assembly work-in-progress on the table with QR codes.

V. CONCLUSION

This paper proposed the development concept of an AR assistive application. This AR assistive application gives clear guidance and instruction by visually representing the furniture 3D models. The furniture 3D models are implemented in the augmented environment and can interact with users on mobile devices. The current applications of AR were first evaluated concerning applicability in the furniture industry. Current approaches do not fulfill the requirements such as home-assembly and highly flexible layout in production. A general concept of the AR prototype in the context of the furniture industry has been created. Finally, the implementation along with the result of this AR prototype was described. This work results can be conducted in the future for industrial partners. For instance, generating movement simulations of 3D models or showing step descriptions in text can provide better information about the assembly process.

In future works, the app's performance should be tested in terms of assembly accuracy and time after the implementation phase. This evaluation will provide insights into its user-friendliness for both operators and customers. Additionally, workflows for various types of furniture details will be implemented to facilitate performance comparisons and enhance guideline reproducing speed.

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