Industrial Product Demonstration in Metaverse using XR Technologies

Dawi Karomati Baroroh, Jie-Ke Pan, Shau-Min Chen and Chih-Hsing Chu

***Abstract*— Metaverse is a new medium that seamlessly blends the digital and physical worlds. Development of Metaverse platforms is still in the early stage. Other than social networking, their applications remain limited at this point. This paper proposes a system framework that realizes the idea of industrial product demonstration in Metaverse. The framework consists of three phases that progressively combines virtual with real environments by using extended reality technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). Each phase is implemented by a technical marketing tool: VR exhibition hall, AR catalog, and MR product layout. These applications allow potential customers to evaluate a series of industrial coolers via real-time interaction and enable remote marketing with novel user experience. This work provides a foundation for implementing the industrial Metaverse.**

***Keywords*:** Metaverse; product demonstration; marketing; VR; AR; MR.

I. Introduction

Metaverse has been gaining enormous attractions in both the business and technology worlds since 2021 [1, 2]. An Metaverse is a virtual space in which users can interact with a computer-generated environment and other users in real-time. It creates novel user experiences in an immersive manner, which is highly valuable in entertainment, gaming, and social networking. Metaverse expands traditional web surfing or real-world interactions into 3D virtual space exploration, thus overcoming physical limitations [3]. One driving force behind the rise of Metaverse is the recent COVID-19 pandemic. With social distancing and travel restrictions worldwide, people start to look for new methods of remote interactions and networking in a digital world. Metaverse has emerged to serve this purpose since 2021. Its technical development or universal deployment is still in the early stage. People are uncertain about its practical use in industry with limited implementation or successful cases [4].

Implementing an Metaverse usually involves immersive technologies such as virtual reality (VR), augmented reality (AR), and mixed reality (MR). Extended Reality (XR) is a collective term containing VR, AR, MR, and everything in between. Figure 1 shows the progress from a virtual would to real environment along the virtuality-reality continuum. XR technologies interact with users in real-time through various forms of sensory feedback like visual, auditory, haptic sensory, and their combinations to create an immersive environment in the Reality–Virtuality continuum [5, 6]. In this continuum, VR is a fully immersive technology in which users interact with a 3D virtual environment generated by computer graphics. AR enhances user's situational awareness by overlaying relevant virtual content onto a real scene. MR is a step beyond AR by combining physical reality with digital content in a way that enables real-time interaction with and among real and virtual elements. VR/AR/MR provide either high immersion by displaying the content on special devices such as head-mounted devices (HMDs) and cave automatic virtual environments (CAVEs) [7], or low sense of presence with computer screens and smartphones. User interfaces in XR applications include common input devices such as keyboards, mice, and touch screens, or advanced functions like voice, eye-tracking, and gesture [5, 6, 8].

XR technologies provide effective solutions for marketing and advertisement. The past study [9] investigated how purchase intent (response) is stimulated and reinforced by online information exposure (stimulus) during the early stage of the COVID-19 pandemic. [10-12] analyzed various elements of that entices buying behaviors via marketing. Marketing activities must entice purchase intentions and customer's interests. Product demonstration is considered an effective marketing means to enhance customer purchase intention, especially for engineering products. Empirical studies [13, 14] show that the use of VR/AR/MR can provide both hedonic (e.g., enjoyable shopping experience) and utility values (e.g., product knowledge). However, there is a lack of studies on how Metaverse supports industrial product demonstration as an integral part of marketing campaign of a company.

To address such a need, this study proposes a system framework of industrial product demonstration in an Metaverse. The framework consists of three phases in which virtual and real environments are progressively merged using XR technologies to enhance customer acceptance and intention. The Metaverse thus constructed provides a new communication medium of product presentation for potential customers to remotely obtain and evaluate details of industrial coolers. Test results of implementing the proposed framework shows the potential of the Metaverse in industry. This work is a preliminary endeavor of expanding the idea of Metaverse from social networking to other fields. The remainder of this paper is organized as follows: the system framework of industrial product demonstration in the Metaverse is described in Section 2. Sections 3-5 provide detailed explanations of XR applications in each of the three phases. The last section gives conclusion remarks on this work.

This work was financially supported by the Ministry of Science and Technology of Taiwan under grant number 109-2221-E-007-064-MY3.

D. K. Baroroh, J.-K. Pan, S.-M. Chen and C.-H. Chu are with Department of Industrial Engineering & Engineering Management, National Tsing Hua University, Hsinchu, Taiwan.

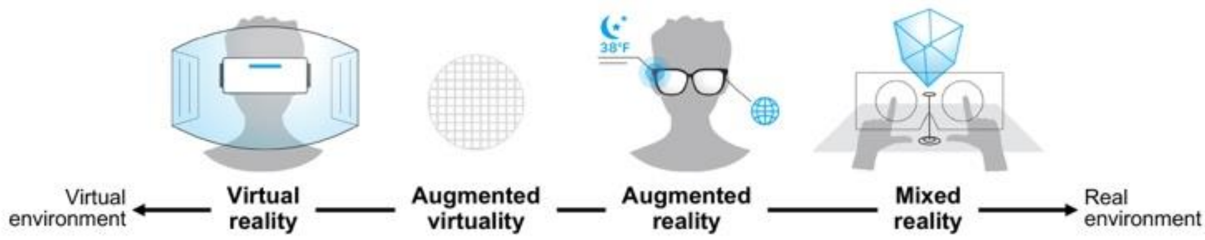

Figure 1. XR in virtuality-reality continuum.

II. RESEARCH METHOD

The main contribution of this work is to propose a system framework that demonstrates industrial product in an Metaverse. The framework consists of three phases that combine virtual with real environment using different XR technologies to progressively enhance customer's acceptance and intention to buy industrial coolers. Figure 2 shows the proposed framework and XR applications in each phase: VR exhibition hall, AR catalog, and MR product layout, which presents product information from the marketing to the engineering perspectives in the virtuality-reality continuum.

The first phase of the Metaverse is a 3D VR exhibition space that displays a product family of industrial coolers mimicking a real hall. Wearing a VR goggle, new or potential customers can freely move around within the space in an immersive manner, and thus obtain general information of the product company such as the company history, mission statement, technological advancements, and services. They can also visualize 3D model, functional capability, and potential applications of each cooler in the form of multi-media. The 3D models in display are imported from CAD software and rendered in Blender. The VR application is developed using C# in the Unity 3D engine. A non-immersive version is deployed with WebGL for users to access via browsers supporting WebGL (Web Graphics Library), Wasm (WebAssembly), and JavaScript. The virtual exhibition does not require user verification. This open design may increase its exposure to the public for marketing purpose.

The second phase is implemented as an AR application of 3D interactive catalog, which is designed for customers who have expressed an interest in the product and want to understand technical details about it. The catalog can be initiated from two different ways. First, each product model existing in the VR exhibition space has a corresponding URL link to its catalog. Also, the catalog automatically shows up by scanning the product image on a traditional product flyer. This phase emphasizes on real-time interactivity with each machine and providing detailed specifications for technical assessment. The AR application is created using C# in Unity. Vuforia enables image scanning and model recognition from a product flyer after a model training process. Lean Touch asset is added to the Unity project to provide 3D manipulation functions of the product models. This asset allows direct object manipulation by finger touch in mobile applications. Users can trigger an explosive view of a chosen product model. In this view, an animation also shows how the model is assembled from a set of components in 3D space, supported by Post Processing and DOTween assets. Those plug-in assets improve the usability of the AR application. At the same time, a pop-up window presents detailed information about each product model as well as comprising component. The AR application operates in iOS 14.0 and above.

The last phase of the Metaverse is a MR application for product layout in a real environment. The application is only accessible to serious buyers who want to assure the spatial arrangement of a specific product on their shop floor. For this purpose, an essential function is to detect collision between a chosen product model and existing objects in a real environment. Such collision detection must be running in real-time during the layout process. An industrial cooler is designed to reduce the temperature of manufacturing equipment that generates excessive heat in use, such as machine tools and SMT (surface mounting technology) machines. A common scenario is to accommodate the cooler to the heat source in terms of spatial arrangement. In this case, collision detection between the cooler (virtual) and existing objects (real) helps to achieve a suitable arrangement. The MR application also displays the final machine appearance and its actual dimension (height, width, and length). It is developed by using Swift in Xcode (version 12.4). Apple's ARKit v4 is used for depth sensing and scene construction from real environment. The user interface is designed by SwiftUI. The application involves the use of LiDAR sensors, which are supported by iPad Pro v4 above with operating system iOS 14.0+.

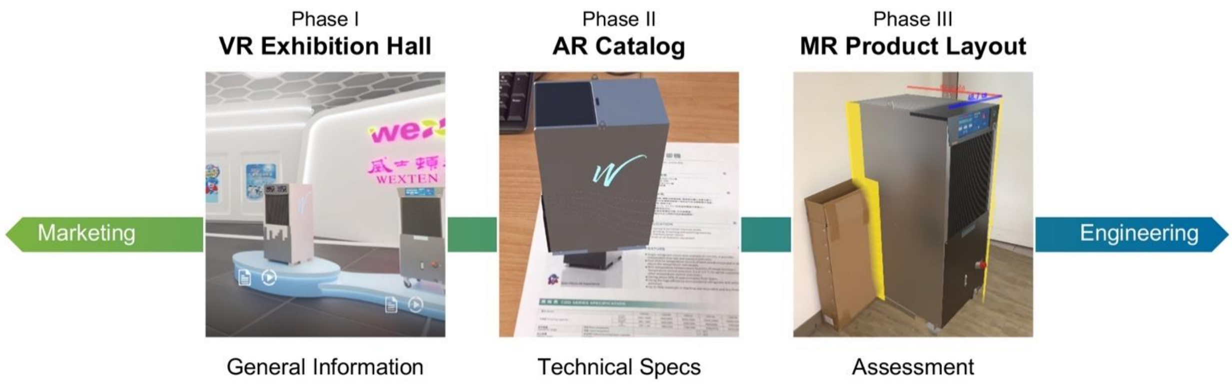

Figure 2. Proposed research framework for an industrial Metaverse.

III. PHASE I: VR EXHIBITION HALL

A traditional approach to demonstrating industrial product is by holding an offline exhibition or similar marketing event. The COVID-19 pandemic imposes severe restrictions on travel and face-to-face meetings. To transform physical activities into virtual but realistic forms is an effective solution. Metaverse and related immersive technologies thus play an important role in new technical marketing and product demonstration during or even after the recent pandemic. This section introduces the implementation results of the proposed framework.

The VR application offers the panoramic view of a highly realistic 3D exhibition hall. Figure 3 presents a common use scenario in which potential customers wearing a VR headset can explore the exhibition in an immersive manner by moving freely within the virtual space. They can zoom in and out by clicking on a view button (see Figure 3) for an enlarged/shrinked view of the information presented in the space (Figure 4) and the business achievements of the company. Multi-media data is also embedded into the virtual scene to introduce the company and its products in a comprehensive way.

Users can closely observe each cooler model in display from different angles and distances. Each cooler model provides two buttons, play and information, for showing general information of the product. For example, Figure 5 simulates the synchronous dual-temperature control (room and liquid temperature) when the cooler is working with a machine tool. This feature engages users by creating highly interactive experience.

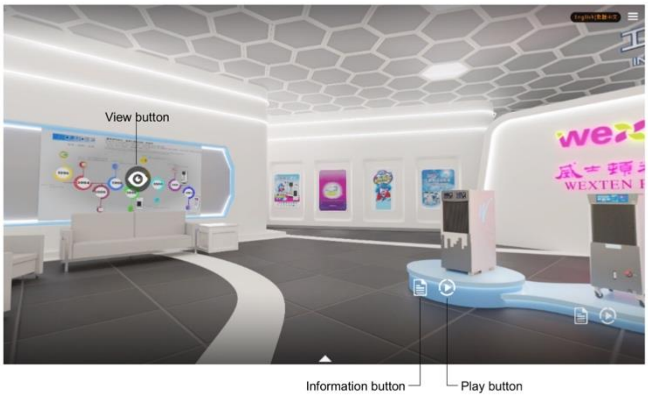

Figure 3. Panoramic view of the VR exhibition hall.

Figure 4. The company and product history.

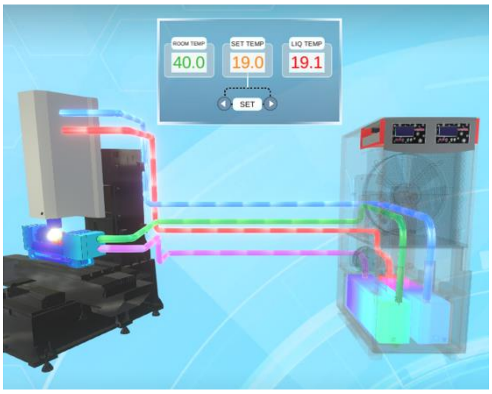

Figure 5. Simulation of heat transfer for a chosen cooler model.

IV. PHASE II: AR CATALOG

After customers became interested in a product, they usually want to evaluate its technical details for further purchase decision. Traditionally, the related information is provided by product flyer, website, or email, which are less interactive and responsive. The Metaverse works as a new communication medium for better information sharing and compiling. The proposed AR catalog can be initiated from two different methods. First, users can access to this application directly from an URL link embedded in the VR exhibition hall. In contrast, it can start from scanning the machine image on a product flyer. This functional feature is designed for customers that already have the company flyer or brochure. The product information can be updated with high flexibility using the AR catalog.

The AR catalog mainly consists of four functions: (1) scanning and tracking machine images, (2) 3D object manipulation (rotating, translation, and scaling), (3) displaying the assembly process of product model in an animation, and (4) presenting the technical specifications of machines. These functions are designed based on user requirements and marketing strategy of the product company. After a target machine has been selected, the AR application prompts the user a message of "READY TO SCAN" (see Figure 6a). This message instructs the user to focus the camera of a mobile device on the corresponding machine image on the product flyer. A green focus box then appears and indicates the image scanning and tracking is ready to work. The machine's name also appears to confirm with the subsequent information retrieval (Figure 6b), which brings up a 3D product model right above the image on the product flyer. Figure 7 shows the user interface of the AR catalog.

(a) (b)

Figure 6. AR catalog opening stages: (a) ready to scan, and (b) scanning the machine's image in catalog.

Figure 7. AR catalog interface.

In addition, the product model will quickly rotate 45o clockwise after the user clicks on the button [ ] in the interface (Figure 8a). Scaling up and down are controlled by two-finger dragging on the screen, which correspond to zoom in and out, respectively (Figure 8b). Pressing the play button [ ] starts an animation that shows the assembly process of the product from individual components in an explosive view. This view reveals the interior of the product in detail as seen in Figure 8c. Next, pressing the information button [ ] pops up the technical specifications of the machine including dimensions, weight, cooling capabilities, power consumption, and installation procedure (see Figure 8d). The user can close the catalog by pressing on the exit button [ ].

(a)

(b)

(c)

(d)

Figure 8. Demo of 3D AR Catalog: (a) rotating, (b) scaling up, (c) exploding, and (d) displaying detailed information.

A series of tests are conducted to determine optimal use conditions for the AR catalog, which are influenced by environmental factors such as light condition, focus distance, and view angle. The test results indicate that the image scanning and recognition functions perform best with a 50-cm distance, 45-degree from the top front side, and spot as well as directional light. They also reveal several limitations. First, the object recognition function is established through a training process based on a chosen image for each product model. Therefore, a change in the target image target may affect the stability of the recognition result. Second, the AR catalog can only scan one image at a time. When there are multiple images in the scene, only one will trigger the recognition. The AR application is developed for iOS running on iPhone 12 and iPad 4 above. It does not support the use of devices running Android.

V. PHASE III: MR PRODUCT LAYOUT

B2B buyers usually make purchase decisions based on assessment of a product's technical specifications and compatibility with the working environment. Traditionally, the product manufacturer may want to send field engineers or sale representatives to do on-site evaluation and discussion with the buyers. The recent pandemic almost prohibits such a physical visit, especially to other countries. Moreover, there is a need of on-site tools for evaluating whether a new product properly works with existing equipment on the shop floor. The evaluation result frequently dominates the final purchase decision for auxiliary or peripheral machines like industrial coolers. The proposed MR product layout application provides effective solutions for both needs mentioned above.

This application precisely overlays a chosen product model with a real environment. The model is a realistic 3D representation of the actual product with the same appearance (color and shape) and dimensions (height, width, and length). Users can freely move the model in 3D space to determine if collision with existing objects occurs at a specific location. The collision detection is performed in real-time during the moving process. The collision location is also highlighted with a bright color in the MR scene to provide a visual cue for users to continuously adjust the model position. This functional feature improves the spatial reasoning of the product installation with instant feedback.

The MR application supports collision detection of four different models, which can be chosen from the home menu (see Figure 9a). After selecting a specific machine, a gesture-based guide pops up to instruct about how to use the function (see Figure 9b). Figure 9c shows that users can freely place the machine to any position in real environment by tapping fingers. Figure 10 shows the dimensions of the chosen machine when it is successfully positioned in 3D space. Users can interactively adjust the machine's installation position to avoid collisions. The MR application works on mobile devices with iOS version 14.0 and above. Preliminary test results suggest that users hold the device within a distance range of 0.5 to 1.5 m to real objects in indoor environment. A bright light condition like sunshine may cause depth sensing to malfunction, and thus the application is not guaranteed to perform well outdoors.

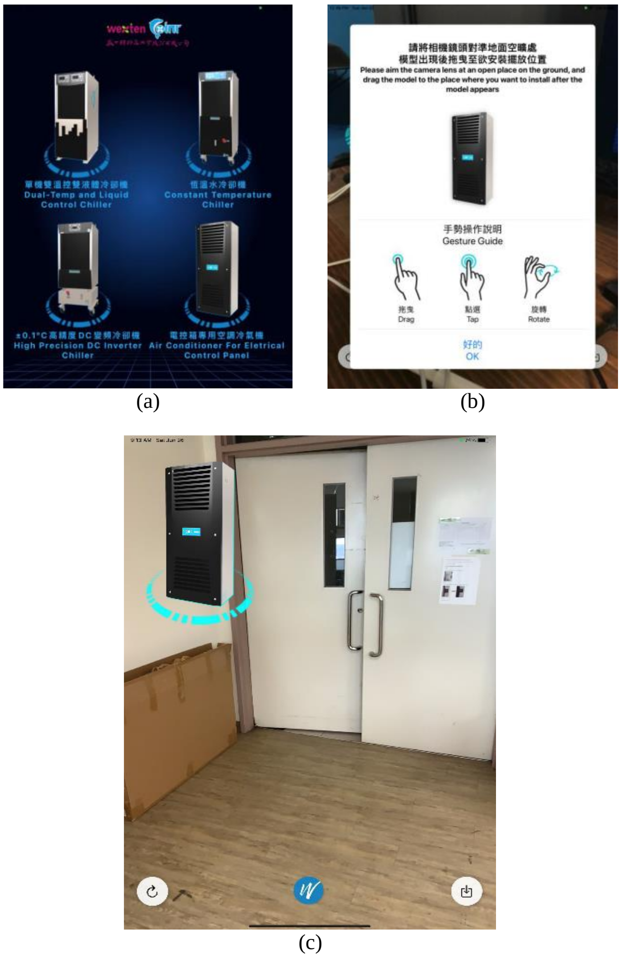

Figure 9. Demo of MR layout tool: (a) product list, (b) gesture interface, and (c) machine placement in 3D space.

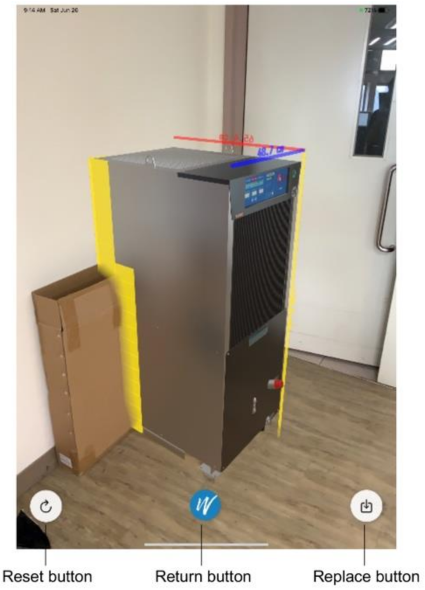

Figure 10. Functional features of MR layout tool.

VI. CONCLUSION

The recent COVID-19 pandemic has greatly impacted the global manufacturing industry, especially limiting marketing activity and product promotion. To remain competitive in the market, companies started to pursue new marketing tools that overcome the restrictions imposed by the pandemic. On the other hand, the Metaverse has emerged as a novel way of social networking and interactions, which may provide effective solutions for this need. Therefore, this study proposed a system framework that realizes a Metaverse for technical marketing and industrial product demonstration. The Metaverse consists of three phases implemented by XR technologies that remotely communicates marketing and engineering information for a product series of industrial coolers. First, a VR exhibition hall allows customers to visualize the product models in an immersive environment. They can obtain business information about the products and the manufacturer by freely moving in the hall. Second, an AR catalog allows existing customers to access to most recent technical specifications of individual products from a product flyer. 3D product models appear in a real scene by scanning product images on the flyer. An animation simulates the assembly process of a product from its components in space and detailed information of each component. Lastly, a MR product layout tool assists to determine whether a product model can properly fit into a work environment with existing objects. Users can freely move the model within the environment with instant feedback of collision detection, thus arranging the installation location on the shop floor. Various use scenarios demonstrate how the three XR applications help potential customers make a purchase decision in virtual spaces. This work is a one of the earliest attempts to realize Metaverse in technical product marketing. Future work can integrate the idea of NFT (Non-Fungible Token) into the existing Metaverse.

REFERENCES

[1] J. Kim, "Advertising in the Metaverse: Research Agenda," *Journal of Interactive Advertising*, vol. 21, no. 3, pp. 141-144, 2021. (DOI: 10.1080/15252019.2021.2001273)

[2] S.-M. Park and Y.-G. Kim, "A Metaverse: Taxonomy, Components, Applications, and Open Challenges," *IEEE Access*, vol. 10, pp. 4209-4251, 2022. (DOI: 10.1109/access.2021.3140175)

[3] S. S. Cha, "Metaverse and the Evolution of Food and Retail Industry," *Korean J. Food Heal. Converg*, vol. 8, no. 2, pp. 1-6, 2022. (DOI: 10.13106/kjfhc.2022.vol8.no2.1.Metaverse)

[4] Y. Zhao *et al.*, "Metaverse: Perspectives from graphics, interactions and visualization," *Visual Informatics*, vol. 6, no. 1, pp. 56-67, 2022. (DOI: 10.1016/j.visinf.2022.03.002)

[5] A. Suh and J. Prophet, "The state of immersive technology research: A literature analysis," *Computers in Human Behavior*, vol. 86, pp. 77-90, 2018. (DOI: 10.1016/j.chb.2018.04.019)

[6] H. B. Santoso, D. K. Baroroh, and A. Darmawan, "Future Application of Multisensory Mixed Reality in the Human Cyber—Physical System," *South African J. Ind. Eng.*, vol. 32, no. 4, pp. 44-56, 2021. (DOI: 10.7166/32-4-2551)

[7] J. Carmigniani, B. Furht, M. Anisetti, P. Ceravolo, E. Damiani, and M. Ivkovic, "Augmented reality technologies, systems and applications," *Multimed. Tools Appl*, vol. 51, no. 1, pp. 341–377, 2011. (DOI: 10.1007/s11042-010-0660-6)

[8] T. E. Papadopoulos, K, T. H. Kaskalis, G. Evangelidis, and S. Sylaiou, "Interactions in Augmented and Mixed Reality: An Overview," *Appl. Sci*, vol. 11, no. 8752, pp. 1-24, 2021.

[9] S. Laato, A. K. M. Islam, N, A. Farooq, and A. Dhir, "Unusual purchasing behavior during the early stages of the COVID-19 pandemic: The stimulus-organism-response approach," *Journal of Retailing and Consumer Services*, vol. 57, 2020. (DOI: 10.1016/j.jretconser.2020.102224)

[10] H. J. Chang, M. Eckman, and R. N. Yan, "Application of the stimulus-organism-response model to the retail environment: The role of hedonic motivation in impulse buying behavior," *Int. Rev. Retail. Distrib*, vol. 21, no. 3, pp. 233–249, 2011. (DOI: 10.1080/09593969.2011.578798)

[11] C.-C. Chen and J.-Y. Yao, "What drives impulse buying behaviors in a mobile auction? The perspective of the Stimulus-Organism-Response model," *Telematics and Informatics*, vol. 35, no. 5, pp. 1249-1262, 2018. (DOI: 10.1016/j.tele.2018.02.007)

[12] M. Moghaddasi, J. Marín-Morales, J. Khatri, J. Guixeres, I. A. C. Giglioli, and M. Alcañiz, "Recognition of customers' impulsivity from behavioral patterns in virtual reality," *Appl. Sci*, vol. 11, no. 4399, pp. 1-18, 2021.

[13] U. Choi and B. Choi, "The Effect of Augmented Reality on Consumer Learning for Search and Experience Products in Mobile Commerce," *Cyberpsychology,behavior, and social networking*, vol. 23, no. 11, pp. 800–805, 2020. (DOI: 10.1089/cyber.2020.0057)

[14] E. Moriuchi, V. M. Landers, D. Colton, and N. Hair, "Engagement with chatbots versus augmented reality interactive technology in e-commerce," *Journal of Strategic Marketing*, vol. 29, no. 5, pp. 375-389, 2020. (DOI: 10.1080/0965254x.2020.1740766)