AR Simulasi: An Augmented Reality Real-Time Cloud-based Simulation for Off-Site Monitoring in Industrial Manufacturing Application

Siti Aisyah Jaafar[1*], Sukarnur Che Abdullah[1], Mohammad Azzeim Mat Jusoh[1], Farok Azmat[2], Ahmed Jaffar[1]

[1] Faculty of Mechanical Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, MALAYSIA.
[2] Faculty of Computer and Mathematical Science, Universiti Teknologi MARA, Shah Alam, Selangor, MALAYSIA.
*Corresponding Author (Tel: +601 891 11366, Email: sitiaisyahjaafar9@gmail.com).

Abstract

The conventional AR-IoT applications only specialize in the localized area for on-site application, thus leaving a research gap in the utilization of Augmented Reality (AR) for off-site monitoring purposes. Thus, this paper introduces AR-Simulasi, the use of AR as support to off-site IoT monitoring data visualization. An experiment investigates the ability to establish an off-site monitoring system using the AR visualization approach for the AR-Simulasi application. This study applies to a simple material handling system, which is a color sorting conveyor. The real-world machine was re-designed in CAD and imported into Unity to create a working simulation. The simulation is in-sync with the movements of the real machine through the communication between smart sensors and ESP32 microcontrollers. The connection is cloud-based and using MQTT to communicate between different devices. The AR-Simulasi application is easily accessible and can be used to view the real-time processes of the conveyor in 3D visualization. The number of colored cubes, color errors, and several controls are projected in the application's interface. The relationships between accuracy and augmented simulation error were investigated. The result shows the maximum lag time of around one second. The presented results show great potential for improvements in the current AR-IoT monitoring applications for industrial uses.

Disciplinary: Mechanical and Manufacturing Engineering, Computer Science, Information Technology.

Cite This Article:

Jaafar, S. A., Abdullah, S. C., Jusoh, M. A. M., Azmat, F., and Jaffar, A. (2021). AR Simulasi: An Augmented Reality Real-Time Cloud-based Simulation for Off-Site Monitoring in Industrial Manufacturing Application. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies, 12*(9), 12A9D, 1-9. http://TUENGR.COM/V12/12A9D.pdf DOI: 10.14456/ITJEMAST.2021.172

1 Introduction

For the past decade, the emergence of Augmented Reality (AR) for the industrial revolution 4.0 (IR4.0) has attracted much attention as a tool that is versatile, flexible, and provides a higher degree of human-digital interactions (Lavingia and Tanwar, 2020).

The manifestation of Augmented Reality and the Internet of Things (IoT) in recent technology has spiked interest in many industrial sectors due to its flexibility and intelligent interface that has proven to improve human-digital interaction (van Lopik et al., 2020). The rise of AR usage is also based on its applicability in assistive systems with scientific and industrial interest and regular launches of new products (de Souza Cardoso et al., 2020) with the implementation of AR technology in different fields such as education, farming, and manufacturing. AR has been used as a tool for entertainment back in the years such as for social media filters, gaming, and advertisements. New devices with higher resolution and quicker response can be used with the advances in ICT technology and provide solid results in a compact size (Chylinski et al., 2020).

2 Literature Review

In recent off-site IoT monitoring, the integration with AR technology is still minimum. One example of IoT monitoring is the use of textual components such as texts, numbers, and graphical information to visualize data (Mehta et al., 2018). Healthcare providers have also implemented the idea of IoT monitoring applications to replace ward rounds and use smart sensors and their smartphone devices to monitor patients in the hospital to save time and receive emergency notifications faster (Rajkumar et al., 2018). IoT monitoring has been widely used over recent years for various functions such as agriculture, healthcare, manufacturing, and education (Khan et al., 2020). Figure 1 shows the schematic structure of the current AR-IoT applications for on-site monitoring.
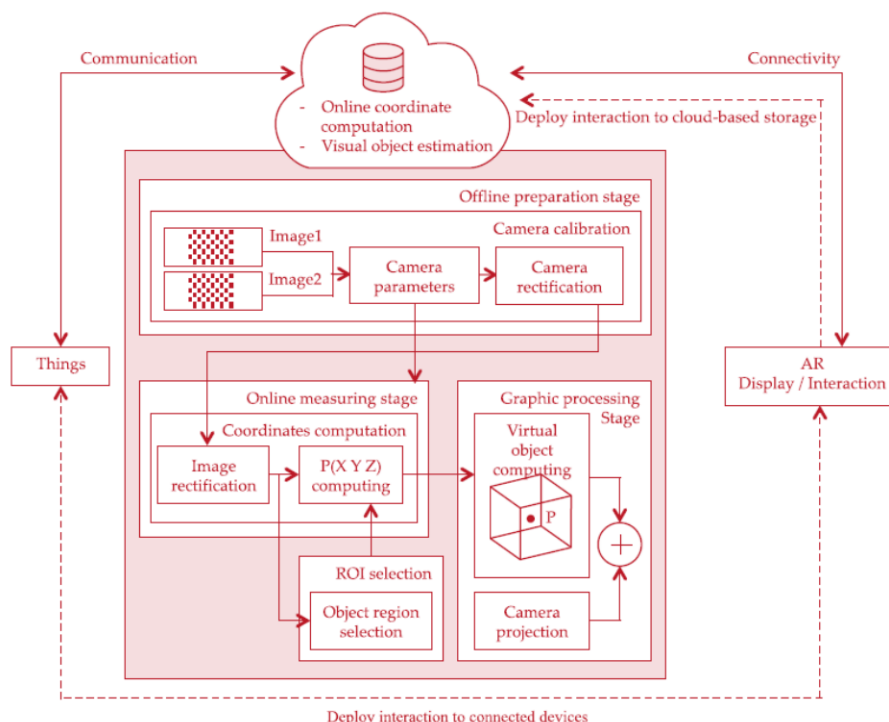

Figure 2: Schematic framework of existing AR-IoT applications

Most of the AR-IoT applications involve image processing capabilities. In which, the user needs to scan using camera projection and the information will be imposed over the scanned item in the AR environment in their devices (Egger and Masood, 2020). Thus, allowing them to view certain information about the scanned item through AR.

In this study, AR simulation is applied to the off-site location for remote IoT monitoring. By definition, AR simulation is an animation that, in real-time, is synchronized with the motions of the real machine. The interaction between intelligent sensors, cloud connectivity, and the applications induced the comportment of the simulation movements. This requires MQTT to communicate between different devices (Patel and Doshi, 2020).

The objective of this paper is mainly to determine whether it is possible to create an off-site AR-IoT monitoring application. Other than that, the objective of this paper is to also apply the coding algorithm to create the AR-Simulasi application. Finally, to evaluate the performance of the application for its accuracy, coverage, and error detection in the augmented environment.

The uniqueness of this study exists in the fact that the AR interface can be used as one of the off-site IoT monitoring applications. Other than that, AR simulation is also developed in this study that moves in real-time in response to the real moving process.

3 Method

In this research work, a mixed approach was applied to discover the research gap in the recent AR-IoT monitoring developments. With in-depth reviews to discover the most recent development of AR-IoT in monitoring for manufacturing industries to obtain the current challenges and disparity in AR-IoT applications, and discover research gap.

The subject used for the AR simulation monitoring would be a simple material handling system. In which, a color sorting conveyor system was used for this study to be the material handling unit and as a subject for the process monitoring to occur. In this study, the development process begins with applying the engineering design method, by fabricating the material handling system, which is the color sorting conveyor system.

The Microcontroller Unit (MCU), ESP32 was used and merged with the built-in Wi-Fi and Bluetooth networking for multiple device access (Andreas et al., 2019). The sensor that was used for the color sorting conveyor was the TCS3200 color sensor module. The schematic setup for the connection between ESP32, TCS3200, and servo motor is shown in Figures 2 and 3.
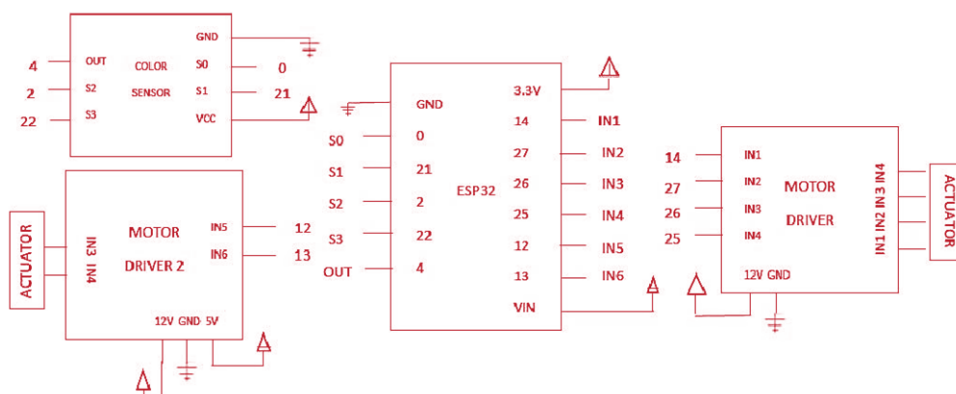

Figure 2: Schematic diagram of hardware connections for IoT devices
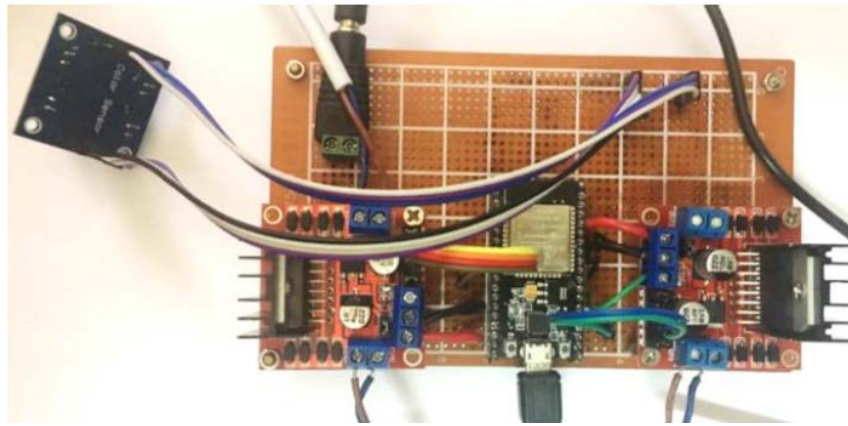
Figure 3: IoT system layout for conveyor color sorting

The research process continues with the development of a 3D CAD model for the conveyor system. Hence, the subject used for this project is a simple material handling process, which is a colored cube sorter conveyor system. By using the reverse engineering method, the conveyor system was re-designed in CATIA part design. It was then assembled in CATIA assembly for a completed color sorting conveyor machine. In Figure 4, the CAD model of the color sorting conveyor system was successfully developed.
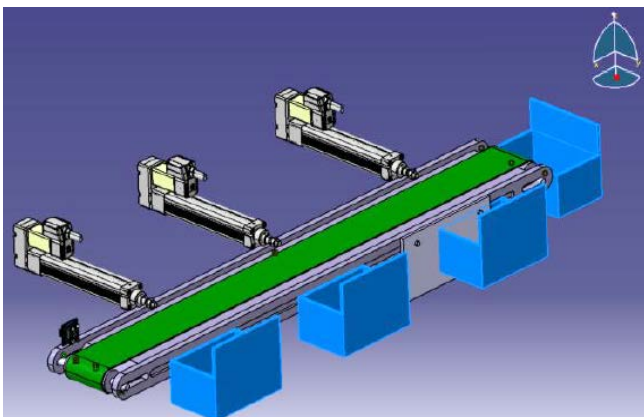

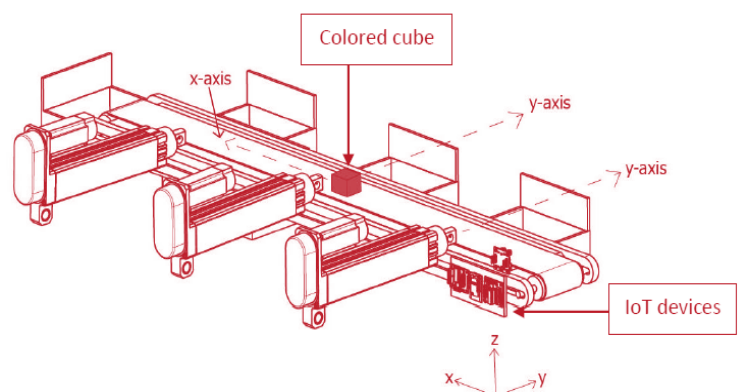**Figure 4**: CAD design of color sorting conveyor machine.

Figure 5: Movement axis for AR conveyor machine animation.

The CAD design of the conveyor is then imported into Unity 3D. Due to the inability of Unity to read .cad files, it was converted to a .obj file by using Blender. Blender has the advantage of protecting the integrity of the sharp edges and small parts of the machine (Bellalouna, 2020). In Unity, C# coding was used to program the contents. Code editor Visual Studio was used to edit the program to allow the commands to be transferred from the cloud. The received data is then projected to initiate movements in certain parts of the machine. In which, for the movement in y-direction will be linear actuators, and colored cube when is pushed to respective buckets. The colored cube will move in the x-direction when it is moving along the belt as in Figure 5.

This study continues with the development of a new algorithm that implants the use of AR for off-site IoT monitoring. The new AR-IoT simulation monitoring algorithm is adapted from the existing AR-IoT crop monitoring project (Phupattanasilp and Tong, 2019). Figures 6 and 7 show the schematic diagram of the process flow for the physical system to the cloud and the AR simulation.
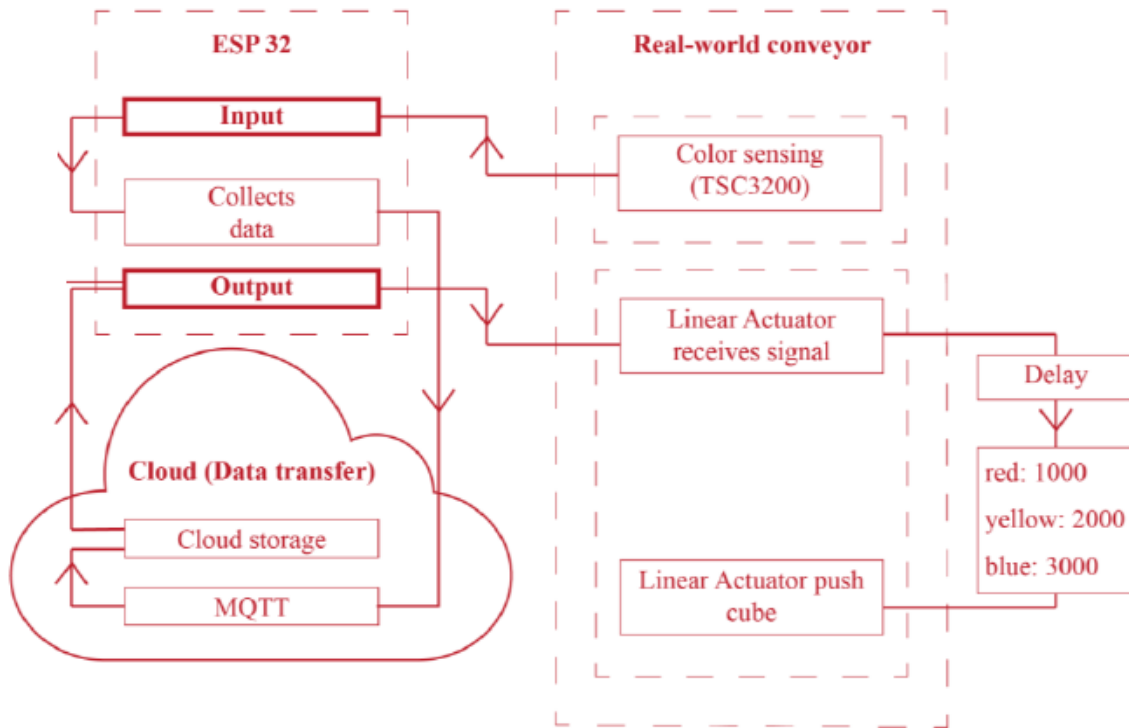
Figure 6: Schematic framework of the real-world conveyor to ESP32 and cloud storage
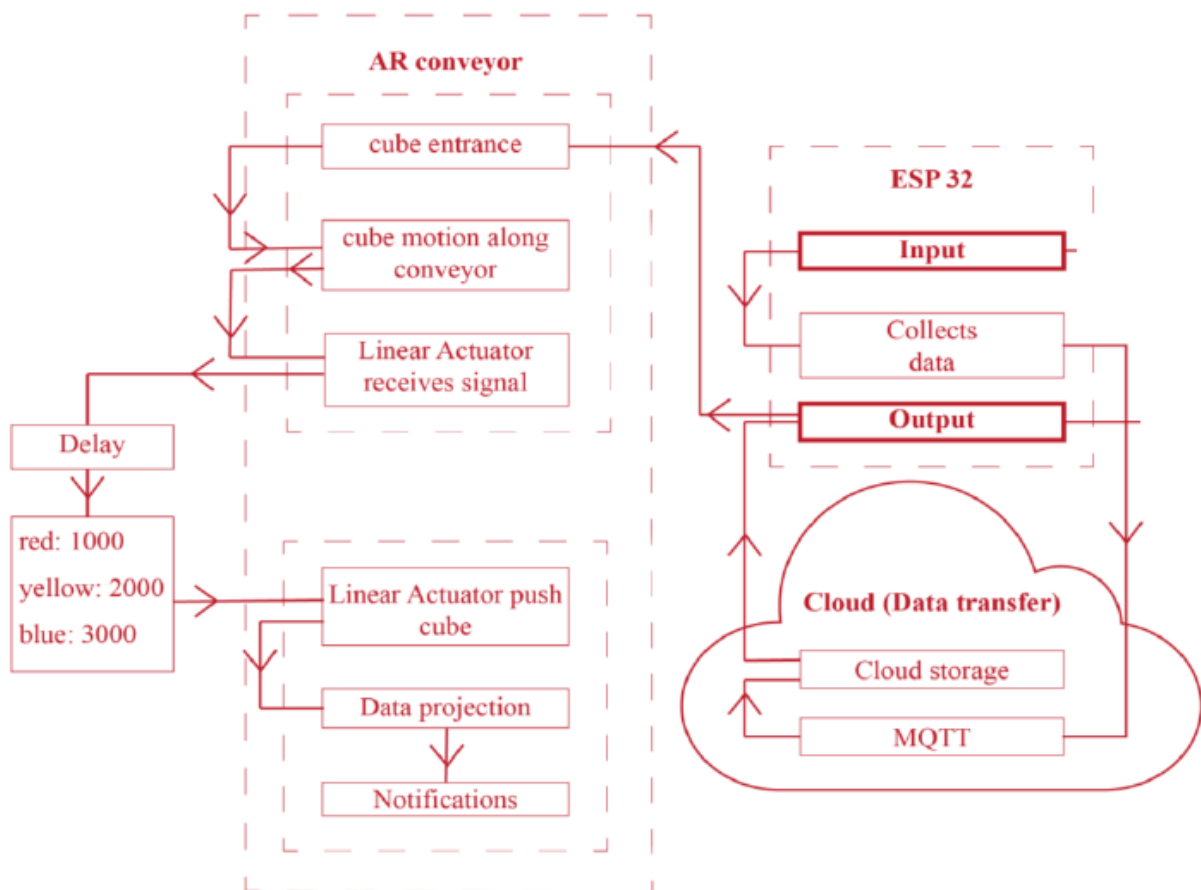

Figure 7: Schematic framework of cloud storage data transfer to AR simulation of conveyor

The algorithm in Figures 6 and 7 shows how the connection relates to each other and how it is established. The communication between devices is also shown. Two programming sets are written, beginning with the one located in Arduino IDE, and the second code is located in Unity 3D. In IDE, the programming uses the C++ programming language and it communicates and sets up

their functions and positions in the color sorting process with the ESP32 board. Contents of the IDE code also include the recognition of the local IP address and details on cloud authorization access. The virtual conveyor coding occurs in Unity 3D and it uses C# language to communicate between the cloud and Unity. The code was edited in the Visual Studio application and debugged. The virtual conveyor code contains two sections which are the Input Sensor and Manager. The role of Input Sensor programming is to organize and work with the data sensors received from the cloud.

During the creation of the virtual conveyor, the AR marker was used as a mark for the projection of the virtual conveyor (Alarcon et al., 2020). The form for the AR marker is in a distinctive code, which is overall customizable to ensure that it is distinctive only to its user. The AR marker was created on the Vuforia webpage, which includes unique codes to import into Unity AR. The AR marker and simulation outcome for this remote AR application as shown in Figures 8, 9, and 10. The AR-Simulasi application is exported directly from Unity using virtual game settings for the creation of the application. Other features such as welcome interfaces and menus are to be further improved in the future.
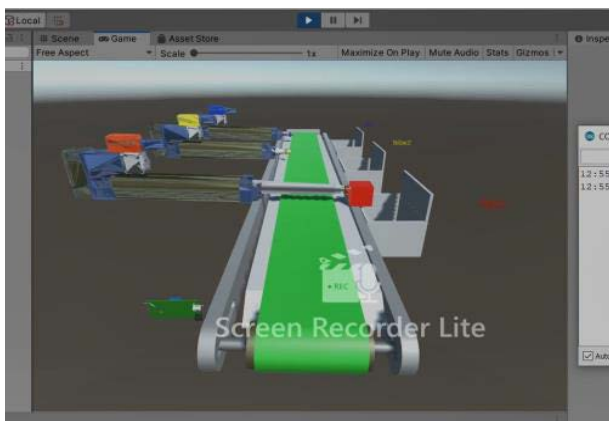

Figure 8: AR marker

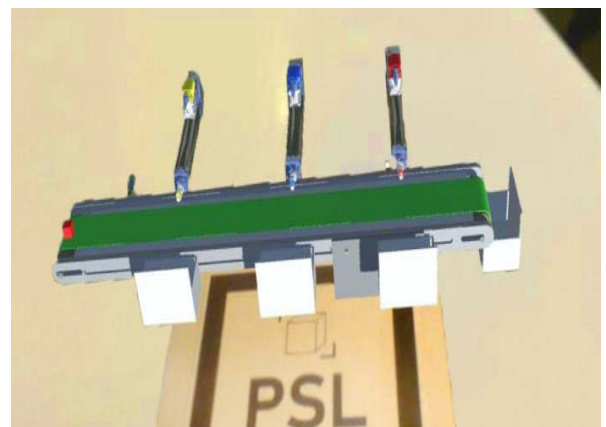**Figure 9**: AR conveyor testing in Unity 3D for data collection.

Figure 10: AR 3D visualization simulation testing

4 Result and Discussion

The findings are analyzed by observing data from 3 sources in real-time. The sources for the data are collected from real-world data (IDE data), and the AR-Simulasi application data (Unity console data). The goal of the real-world measurement is to obtain the true data to calculate the output of raw IoT monitoring data from IDE and AR-Simulasi applications by comparing it to obtain the percentage error for sources 2 and 3 altogether.

Subsequently, the error obtained from IDE would be the raw data for IoT monitoring applications. Therefore, to measure the accuracy in the AR-Simulasi application, the error shall be compared to the data in IDE. The accuracy comparison was analyzed by the compilation of a set of timestamp details. Arduino IDE's serial monitor however shows the timestamps in minutes to milliseconds as in Figure 11, and only up to seconds for Unity console as in Figure 12.

The accuracy of the color sensing process was analyzed and a set of timestamps are collected for each activity that occurs during the color sorting process. The timestamp was taken for each process in the Unity console and IDE serial monitor from off-site. Both data were then compared with the time of the physical conveyor reported by observing the actual on-site operation.

Figure 11: IDE debug showing timestamps up to milliseconds

Figure 12: Unity console debug showing timestamps up to seconds

Figure 13 presents the average timestamps for color sensing response. From this graph, there is minimal difference in the data from the three sources. Figure 14 shows the maximum time lag is one second. This however does not consider the reading in milliseconds. Therefore, on average the maximum lag time is one second.
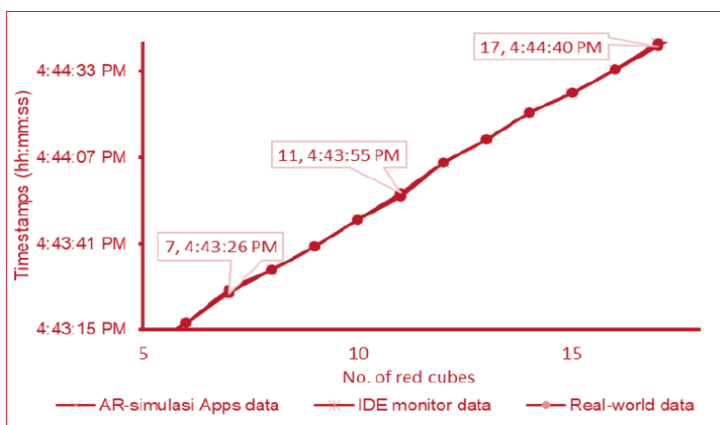

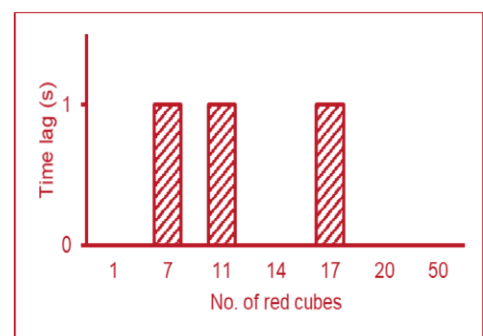**Figure 13**: Graph of overall color sensing timestamps

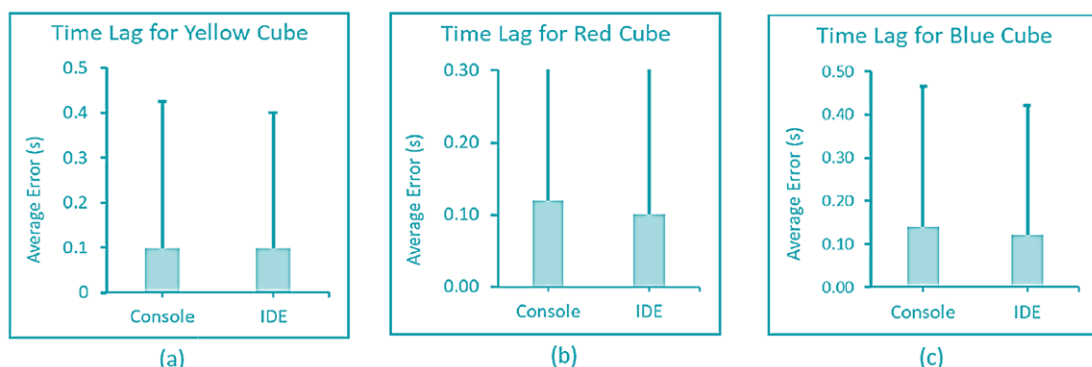**Figure 14**: Graph of time lag (s) for 50 color cubes

Figure 15: Graph of time lag for (a) yellow, (b) red, and (c) blue color

Figure 15 shows the graph of time lag for each of the colors. The average reading is taken, and it shows that the reading fluctuated between different colors. For the red color sensor, the average error is between one to two seconds. While for yellow, it shows a second lagging average and for blue it showed from one to two seconds of lagging. Despite this fluctuation in lagging time, the difference is minuscule.

5 Conclusion

The application of AR-IoT for off-site monitoring was developed and exported as an application. This paper presents the results of accuracy, augmented simulation error, and object interaction. It was shown that for the accuracy, the errors were acceptable in terms of error percentages compared to existing IoT applications' accuracy analysis for monitoring. In addition to that, the Augmented Simulation Error was also assessed and slight coordination and timing errors were shown. However, due to the use of the cloud system for data transfer, there is a lag in information transfer causing the lag in data projection for the AR application.

The findings from this study make several contributions to research areas related to AR-IoT. AR-IoT applications are now verified to be used remotely instead of only localized or on-site. Other than that, the development of AR-Simulasi was able to be applied widely for other case studies to replicate and mimic the real conveyor processes in an Augmented environment. Nevertheless, this paper will provide a research start-up for future studies and analysis to improve the accuracy and efficiency of larger-scale applications. More improvements will need to be done to determine the ability of the remote AR-IoT algorithm to be applied to various industrial and related applications.

6 Availability of Data and Material

All information is included in this study.

7 Acknowledgement

8 References

Alarcon, R. et al. (2020). Augmented Reality for the enhancement of space product assurance and safety. Acta Astronautica, IAA, 168, pp. 191-199. DOI: 10.1016/j.actaastro.2019.10.020

Andreas et al. (2019). Door security system for home monitoring based on ESp32. In Procedia Computer Science, pp. 673-682. DOI: 10.1016/j.procs.2019.08.218

Bellalouna, F. (2020). Industrial Case Studies for Digital Transformation of Engineering Processes using the Virtual Reality Technology. Procedia CIRP, 90, pp. 636-641. DOI: 10.1016/j.procir.2020.01.082

Chylinski, M. et al. (2020). Augmented reality marketing: A technology-enabled approach to situated customer experience. Australasian Marketing Journal. DOI: 10.1016/j.ausmj.2020.04.004

Egger, J. and Masood, T. (2020). Augmented reality in support of intelligent manufacturing - A systematic literature review. Computers and Industrial Engineering, p. 106195. DOI: 10.1016/j.cie.2019.106195

Khan, W. Z. et al. (2020). Industrial internet of things: Recent advances, enabling technologies and open challenges. Computers and Electrical Engineering, 81. DOI: 10.1016/j.compeleceng.2019.106522

Lavingia, K. and Tanwar, S. (2020). Augmented Reality and Industry 4.0. pp. 143-155. DOI: 10.1007/978-3-030-14544-6_8

van Lopik, K. et al. (2020). Developing augmented reality capabilities for industry 4.0 small enterprises: Lessons learnt from a content authoring case study. Computers in Industry, 117. DOI: 10.1016/j.compind.2020.103208

Mehta, R., Sahni, J., Khanna, K. (2018). Internet of Things: Vision, Applications and Challenges. Procedia Computer Science, 132, pp. 1263-1269. DOI: 10.1016/j.procs.2018.05.042

Patel, C. and Doshi, N. (2020). A Novel MQTT Security framework in Generic IoT Model". in Procedia Computer Science, pp. 1399-1408. DOI: 10.1016/j.procs.2020.04.150

Phupattanasilp, P. and Tong, S. R. (2019). Augmented reality in the integrative internet of things (AR-IoT): Application for precision farming. Sustainability, 11(9). DOI: 10.3390/su11092658

Rajkumar, S., Srikanth, M. and Ramasubramanian, N. (2018). Health monitoring system using Raspberry PI. 2017 International Conference on Big Data, IoT and Data Science, BID 2017, 2018-Janua(1), pp. 116-119. DOI: 10.1109/BID.2017.8336583

de Souza Cardoso, L. F., Mariano, F. C. M. Q. and Zorzal, E. R. (2020). A survey of industrial augmented reality. Computers and Industrial Engineering, 139. DOI: 10.1016/j.cie.2019.106159.

Siti Aisyah Jaafar is a student at the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia. She got a Bachelor's degree in Engineering (Hons) Mechanical from Universiti Teknologi MARA (UiTM), Malaysia. She is currently pursuing her Master's degree in Science (MSc) at Universiti Teknologi MARA (UiTM), Malaysia. Her research is related to the Internet of Things and Mixed Reality in Mechatronics and Automation Engineering.

Dr.Sukarnur Che Abdullah is a Senior Lecturer at the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia. He had obtained his Bachelor of Engineering in Mechanical Engineering from Saga University, Japan and a Master of Science in Manufacturing Systems Engineering from the University of Putra Malaysia (UPM), Malaysia. He also obtained his PhD in Information Science from the Graduate School of Information Science, Nagoya University, Japan. His major fields of research are robotic, tactile sensors, humanoid robots and visions, and Advanced Manufacturing Systems Engineering.

Dr.Mohammad Azzeim Mat Jusoh is a Senior Lecturer at the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia. He obtained his BEng (Hons) in Production Mech. Eng. From Saga University, Japan. He earned his Master of Innovation & Eng. Design from Universiti Putra Malaysia (UPM). He obtained his PhD in Information Science from the Graduate School of Information Science, Nagoya University, Japan. His major field of research is Psychophysics of Human Tactile Mechanisms and Engineering Design.

Farok Azmat is a Senior Lecturer at the Faculty of Computer Science, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia. He obtained a Bachelor of Science, Information Systems Management from St. Louis University St. Louis, Missouri, USA, and a Master of Science in Information Systems from The Robert Gordon University Aberdeen, Scotland, UK. His fields of research are Taught Data Communications, Network Protocols, Network Design and Telecommunications.

Prof. Ir. Dr. Hj. Ahmed Jaffar is a Professor at the Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), Shah Alam, Malaysia. He obtained a Bachelor's degree in Mechanical Engineering from Universiti Teknologi MARA (UiTM), Malaysia, and an MBA in International Management from the University of East London, United Kingdom. He earned his PhD in Manufacturing from the University of London (Royal Holloway), United Kingdom. His research encompasses Robotics for Manufacturing Industry.