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Augmented Reality In Smart Manufacturing: A User Experience Evaluation

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Abstract

In recent years, technological advancements including computational capabilities have rapidly increased. This advancement has led to the feasibility of developing advanced technological applications through the integration of Augmented Reality. This article presents an optimal model and application utilising Augmented Reality, Simultaneous Location, and Mapping algorithm for device identification within a smart manufacturing environment. The devices are identified based on their positions by detecting their features utilising the ORB-SLAM algorithm. The device identification is based on the use of markerless identifiers for the purpose of reducing the manual process of pasting markers on every device within the manufacturing plant. This model offers an alternative solution, with the properties of detecting devices based on their position and features. Thus, validation of this approach involved a control group to provide a broad-base evaluation. The results are positive, with the majority of the individuals recommending the adoption of the application and its utilisation within a wider-scale deployment. Specifically, the findings demonstrate that 70% of the users approve of the use of the application in an industrial setup, 65% are satisfied with the accuracy and reliability of the app and 80% recommend the adoption and utilisation of this app in an industrial setup.

Keywords: User Experience, Augmented Reality, Smart Manufacturing, SCADA, Markerless Identification, Computer Vision

1. Introduction

The use of Augmented Reality (AR) applications has modelled remarkable progress toward real-world consumer applications such as health and manufacturing [1]. However, in most cases, this technology faces an order of accuracy and implementation challenges in the success of data transfer, response time, integration of AR, and interface design. However, there have been multiple AR applications developed for diverse purposes, including visual augmentation of a scene [2]. These applications have been applied to different areas due to their potential to enhance user experiences in learning, training, simulation, and other tasks [3].

In consideration of the trends in mobile computational power, the likelihood of the success of the development of an AR-based markerless application is high. The challenge, currently faced by manufacturers in this industry, is the development and optimisation of computer vision-based applications in the manufacturing environment as the manufacturing architectures and blueprints differ from one plant to the other. Additionally, the need to develop an accurate indoor AR application for localisation and augmentation of devices based on their positions within the Smart Manufacturing environment is critical. Hence the need for the concept of transformation and the current industrial environment through digitalization of production [4]. Furthermore, the observation of successful data transfer for enabling successful sensory data transfer from the Supervisory Control and Data Acquisition (SCADA) systems to computer vision applications utilising augmented reality applications need to be further investigated. Subsequently, the need also to implement and integrate augmented reality applications with other systems such as the SCADA system for devices identification based on their positions needs to be investigated.

This paper furthers the adoption of AR technology for deployment in real-time manufacturing applications. Notably by making use of the Orientated Fast and Rotated Brief-Simultaneous Localisation and Mapping (ORB-SLAM) algorithm to detect and recognise devices based on their location within an indoor manufacturing environment. The use of machine vision for device detection, and augmentation based on their features and position within an indoor manufacturing plant is worthy of investigation. Therefore, it is critical for the development and implementation of an AR application that has the capability for acquiring sensory data and augmenting the results based on the device position and features. The objective of this study is, therefore, to; 1) To present and develop an AR application for motor recognition and identification based on their positions and feature within an indoor manufacturing environment; 2) To evaluate the user experience for such an application in a live environment;

The remainder of this paper is as follows. Section 2 discusses the related work. Section 3 presents the model and outlines the systems modelling approach using ORB-SLAM and Bundle Adjustment (BA) algorithm. Section 4 details the experimental results with the paper concluded in Section 5.

2. Related work

In recent years, AR applications have gained a great deal of popularity due to their capabilities to facilitate human-driven activities [5]. AR applications can simulate, assist, and improve processes before actions are carried out. Subsequently, AR applications have also been proven to triple efficiency [6] when compared with more traditional techniques. However, Billinghurst et al. [7] present the comparison between the optical view and video-based AR displays. The author does further outline that problem relating to optical see-through display mainly citing the inaccuracy of the registration between the real and the virtual view images.

This technology supports collaboration, hands-free operation (particularly with the HoloLens technology), is not restrictive, and offers a wide field of view. AR applications are of significance in the virtual object display of information that the users cannot directly detect with their senses [8]. However, implementing AR applications can be time-consuming and costly for the end-user. For that reason, Nguyen et al. present a system titled BlocklyAR for the creation of AR applications using a browser-based interface for use by non-programmers [9]. The system adopts a block-based visual programming approach, with the ability to generate code in different languages for wide deployment of the application. Their system is assessed by 66 end-users, who can download the free-to-use 3D models and apply animations using the BlocklyAR tool. Limitations in the work are discussed; however, the premise of the approach is different from that which is poised in this paper, as the focus is on education and animation, rather than manufacturing and construction support.

A significant portion of AR research also exists within other domains; notably within the education sector. For example, Meletiou-Mavrotheris et al. [10] outline the AR application for use within augmented textbooks. Their research investigates the concept of a living book for creating a virtual augmentation of the learning experience. The work aims to support individuals with poor reading performance and stimulate the learning experience. This demonstrates the technology’s versatility and growth cross-sector; as researched by Abad-Segura et al., who investigates the increasing interest in AR usage in higher education [11]. One such example the authors identify is the use of AR within architecture classes, where the integration of visual analytics can make understanding complex structures more accessible. This view is shared by Lasica et al. who investigate the application of AR within lower secondary schools [12]. The authors outline a program to support teachers when learning AR technologies and how it can be used as a metric for enhancing the teaching and learning process within schools. However, despite the enhancement that AR brings, Rabbi et al. [13] present their concerns relating to the performance challenges such as a real-time and evolving real-world environment. However, Rabbi`s concern does not outline the good that the evolving real-world environment brings to both AR and VR applications. In contrast, Jerome et al. [14] present the usefulness of AR/VR by outlining their importance in both consumer-friendly applications and functionality mainly when accurate positional tracking and seamless 6DoF are developed.

Clearly, AR has the potential to act as a supportive metric within multiple domains. However, the focus of this paper is specifically on the application of AR in the manufacturing sector and evaluating user experience based on the application. In the following section, the system modelling approach is presented.

3. System modelling approach

Since this application focuses on the effectiveness of the AR application in identifying devices based on their positions within a manufacturing environment, a testbed must first be developed before the user experience can be evaluated. The test setup is primarily based on the selection of the correct apparatus before the testbed is developed and modelled. Figure 1 depicts the overall system architecture.

Specifically, Figure 1 presents the sensor configuration model that is based on the use of a proximity sensor which meant that the conveyer belt motors required modification. The motor speed and direction are obtained by attaching the timing disc to the rotational shaft opposite the timing shaft by mounting two space together with the proximity sensor. The sensory data is then obtained through the Arduino microcontroller and then the data gets stored in the Structured Query Language (SQL) database. However, to transfer the data to the AR application, the Wemo microcontroller is utilised by transferring a string of data packets (the size differed depending on how many tests were run to the AR application via WiFi connectivity as indicated in Figure 1.

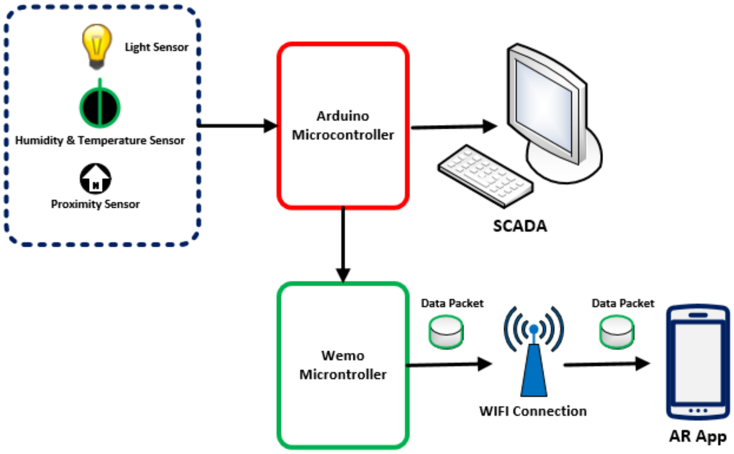


Figure 1. Project architectural structure.

3.1. Apparatus used for designing SCADA system

This section outlines the method used in designing and modelling the prototype for two technologies namely AR application and machine vision technologies utilising the outlined apparatus. The apparatus are assembled in a manner that will satisfy the proposed methodology by being able to meet the development of the scaled model.

The test setup is made up of three (3) sections namely SCADA, AR Application, and Machine Vision. The three sections are based on the software and electronic components. The three sections are divided into three subsections namely; a) SCADA and machine vision design and modelling techniques; b) AR application development setup; c) Machine vision and data transfer protocol.

3.1.1. SCADA and machine vision design and modelling techniques

The following apparatus are selected for the physical testbed development.

- Wemos 8266 WiFi microcontroller
- Arduino Uno microcontroller

- LM35 temperature sensor
- Light Dependent Resistor (LDR)
- Microsoft Visual Studio (C# Language)

Figure 2 outlines the object's design in CorelDraw software. To obtain optimal results from an AR system, the AR application should be coupled with other technologies such as the (SLAM, global position system, and sensors) [15]. The designed objects work in parallel with machine vision application. The machine vision application`s function is to detect and identify these objects based on their colour and shape. The SCADA system then uses the Arduino microcontroller to extract the sensory data from the sensors, then stores it in the embedded SQL database. The SCADA system then acts as the Graphical User Interface (GUI), therefore, upon every change in the sensory data, the SCADA system projects updated data from the user input variables. Following the design satisfaction, the material designs are printed out of the laser cutting machine using wood (which is more affordable and sustainable than Perspex). Subsequently, the components are printed out, and a glue gun is used to mount the components together, and a blue or red cover is used before the individual testing is conducted.

The camera is responsible for the inspection of the objects that pass through the conveyer belt. Once the detection and recognition of the object is complete using the inspection camera, the correct object is marked by a green square on top of the object as indicated in Figure 2. In this application, the identifiable objects are red squared objects.

Figure 2. Object modelling sequence.

3.1.2. SCADA and machine vision design and modelling techniques

The development of AR Technology was based on Unity3D platform. In Unity3D, the Vuforia SDK is also utilised. Unity3D is a complete 3D engine supporting C# scripting, 3D and 2D graphics, physics, sound, and animation [16]. The system development was based on the use of the ORB-SLAM technique. The ORB-SLAM algorithm is used in conjunction with augmented reality due to its ability to solve the following challenges:

- Unknown environments
- Real-time tracking

The device images were modelled in Blender3D and the features were also added for the application to distinguish between the two devices. Due to numerous AR systems using diverse approaches for visual augmentation of the scenes, the selection of the best tracking features are conducted. The natural feature and location-based features were deemed the most relevant as the paper focuses on both the motor and robotic arm identification based on their location and unique feature. However, the natural feature was added with regards to identifying the correct device based on its uniqueness despite the location change. Bearing in mind that this study is conducted on a small-scale plant.

Location tracking is a precondition for any location-based tracking application. The feature detection in this paper is focused on the AR application; however, it was noted that the 2D images (X, Y) coordinates does not have enough data to obtain the entire feature data of the object. Hence the model and creation of the third coordinate of the targeted image was implemented to have a completed 3D imagery by adding the Z coordinate to have (X, Y, Z) coordinates.

The system modelling approach used in this paper for the AR application is depicted in Fig 3. The process in which the three components are developed and their interface functionality to the manufacturing processes are outlined. The system development is based on the use of the SLAM technique. The SLAM algorithm is denoted as a process by which the AR application device calculates the spatial relationship between itself and multiple key points [17].

SLAM is used in conjunction with AR due to its ability to solve the challenges of unknown environments and real-time tracking. Figure 3 outlines the SLAM operation process. The stages are as follows. 1) Inspection for features by applying the SLAM feature algorithm on the devices that are in the manufacturing plant; 2) Upon finding those features, the data is then saved onto the database, and then add the appropriate model (robotic arm); 3) Then compute the coordinates of those features, then store them in the database; 4) Create a WiFi connection between the AR application and the SCADA system; and 5) Additionally, the bundle adjustment algorithm is used to calculate the device positions based on uncertainties.

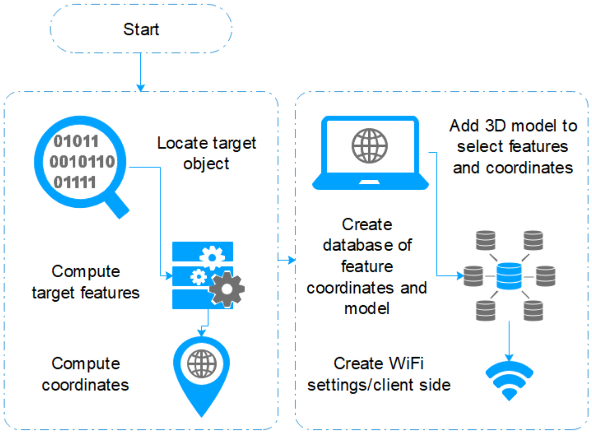


Figure 3. AR application utilising SLAM algorithm.

3.1.3. Machine vision and data transfer protocol

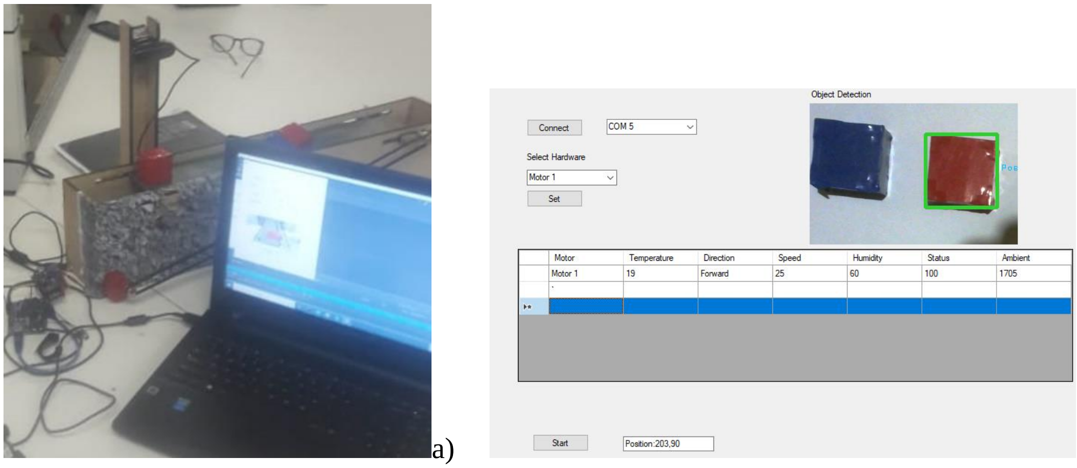
In this section, a method for transferring sensory data is outlined. In addition to the test setup model, a new feature of identifying objects based on their colour and shape within the manufacturing environment utilising machine vision is presented. Machine vision is denoted as the use of a camera or multiple cameras to inspect and analyse objects automatically and this process can be in an industrial or production environment [18].

Machine vision output is incorporated into the SCADA system to display the overall research paper data in one window. The sensory data is then displayed on the SCADA system and using the Wemo microcontroller and WiFi connectivity, the data is shared with the AR application.

The physical configuration is based on the Wemo microcontroller that is connected to the Arduino Microcontroller. Upon the sensory data retrieval from the database, the Wemo microcontroller immediately sends the packet of string/s to the AR application via WiFi connectivity. This process is defined as Machine to Machine (M2M) interface, which is a protocol, within the IoT system where data is transferred from one machine to the other without any human intervention.

However, due to the size and non-complexity of the data packets transfer protocol, the 802.11b protocol was used with reference to the capabilities of the Wemo microcontroller and also the test device compatibility. The test is based on the WiFi connectivity within an indoor manufacturing plant. Through the WiFi connectivity, the data transfer was accomplished using Transmission Control Protocol (TCP)/ Internet Protocol (IP) protocol which is a connection-oriented communication protocol. TCP is arranged to send data packets over the network and ensure that it is delivered to the destination IP.

The sensory data is read from the Arduino microcontroller as a packet of 32 bits string and transferred via the Wemo microcontroller through WiFi connectivity. Figure 4 depicts the machine vision setup method. The initial testing of the machine vision integrated system is based on red squared objects, then blue squared objects as previously outlined.



	Motor	Temperature	Direction	Speed	Humidity	Status	Ambient
	Motor 1	19	Forward	25	60	100	1705
	.						
▸*							

Position:203,90

a)

b)

Figure 4. a). Machine vision application on a small scale for tracking red objects, b) Object detection output on a SCADA system.

Figure 4a) depicts the obstacle tracking based on shape and colour utilising image processing and machine vision techniques. The object recognition in the context of this paper is based on the contour approximation technique, while the colour detection is based on defining image lower- and upper-pixels values. Once the pixel value definition is achieved, the cv.inRange method is used to return the mask of pixel values. Upon having the correct mask, the cv2.bitwise function is then applied to the target image as indicated in Figure 4b).

Additionally, Table 1 outlines the different WiFi (TCP/IP) protocols and data rates derived from ref [19] that were used for data packets transfer from SCADA system to the AR application. The test was based on WiFi connectivity within a Smart indoor manufacturing plant for evaluation of the correctness of the transferred data.

Table 1. Summary TCP/IP data transfer protocol [19].

Source Port			Destination Port
Sequence Number			
Acknowledgment Number			
Data offset	Reserved	Flags	Window (Sliding window)
Checksum			Urgent pointer
Options			Padding
Data			

Table 1 is used based on the size of the dataset that we received during the testing phase. The initial step in the functioning of the SCADA system is to connect the SCADA system to the machine vision application. Once the connection is successful, the hardware (motor 1 or motor 2) is selected and set and the process or application can commence by pressing the start button. Following correct system settings, the sensory data is retrieved and outputted on the SCADA system. Subsequently, the camera is used to detect the objects and the red squared object will be highlighted or marked with a green square over the detected object.

Figure 5 depicts the motors used in this research paper for augmentation of their properties. The ORB-SLAM algorithm is utilised for the identification of the motors based on their position/ location and features in the indoor manufacturing plant. In Figure 5, the motors are identified by a circle shape.

Figure 5. Conveyor belt with motors used for augmentation of device details.

Subsequently, the conveyor belt was already built and is currently used in the manufacturing facility. However, for this research paper, the motors in the conveyer belt were modified by painting them with different colours to give them unique features. By means of this approach, the AR application can detect and augment the motor details based on their colour (unique feature) and the location within the indoor manufacturing environment. This conveyor belt is used as part of the test setup for the physical model testing.

4. Experimental Results

The results projected in Figures 7 to 8 depict the results obtained, based on the object accuracy in terms of the distance and the camera frame from the device camera to the targeted object. These results analysis is based on the recognition of the feature and location-based identifiers for augmented reality applications, utilising the Unity3D platform.

Secondly, this thesis based the direct recognition and identification of objects on the utilising machine vision technology by applying multiple OpenCV libraries in conjunction with Emgu CV libraries for object detection. However, the colour selection section was based on the processing and computing of colour and a green squared identifier was placed on top of the detected object and projected the results on the SCADA system.

Moreover, it has been noted through evidence provided in Figures 6 to 13, that the study did achieve its objectives and the detection of the devices and objects was achieved.

4.1. User evaluation results

To model the application to function as intended, it was necessary to have the input JPEG image sample from the Android camera transferred to the object tracker Unity3D AR database and escort the tracked bounding box onto the preview screen. The sensory data results were taken and stored in the SQL database and after their storage, they were transferred via the Wemo WiFi module, through the WiFi connectivity, as a string of data packets to the AR application. Furthermore, another system analysis were conducted, based on the following:

However, to have a control response rate, the YouTube link and the survey link were sent to 20 users. The results of the survey after the users have seen the YouTube video of the AR application in a Smart Manufacturing plant were required to submit their responses using Google Forms. The reason for this approach is due to the Covid-19 pandemic hitting the globe and as a result movement and access to facilities were limited.

The implementation of the system runtime was based on the size of the data packet transferred from the SCADA system to the AR application. In this context, the SCADA system was acting as the server and the cellphone as the client. Therefore, the client-server connection was based on the basic three-way handshake protocol, synchronisation, and acknowledgment. Based on the computational time frame interval, the SCADA can detect when a packet has been converted into the binary state (0 or 1) and if it is not transmitted, by not receiving the acknowledgment from the AR application, and as a result, the SCADA system will continue to transmit data until the connection is disconnected.

In addition to determining the time intervals for the period it takes the data packets from the SCADA system to the AR application, an OpenCV function was used to calculate the time it took the data to be transferred from the SCADA system to the client, as outlined in the below sample code

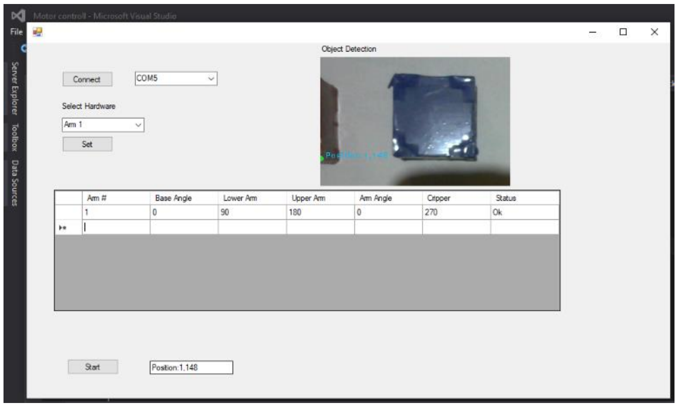
“std::cout << float(clock () - begin_time) / CLOCKS_PER_SEC”.

Subsequently, the data packet transfer rate was measured with four samples distance as indicated in Table 2. The latency test was conducted for the input data, which are transferrable from the SCADA system to the AR application. As indicated in Table 2, the latency increases as the distance increases, however, this does not affect the success rate.

Table 2. Latency and packet rate success rate.

Distance between STA and API (meters)	Ping Latency (ms)	Packet transfer rate (%)
2	150	100%
4	238	100%
8	330	100%
10	420	100%

Table 2 was developed by using the SPEED CHECK application in Android. The application was used to examine if there was a delay in the WiFi reception and how this would influence the data or transmission speed of the data sent. However, it has been noted that the transmission speed does get affected as a result of the distance, but this does not affect the success rate, provided that the WiFi connectivity is still within range. Figure 6 depicts the results of the SCADA system.



COM5

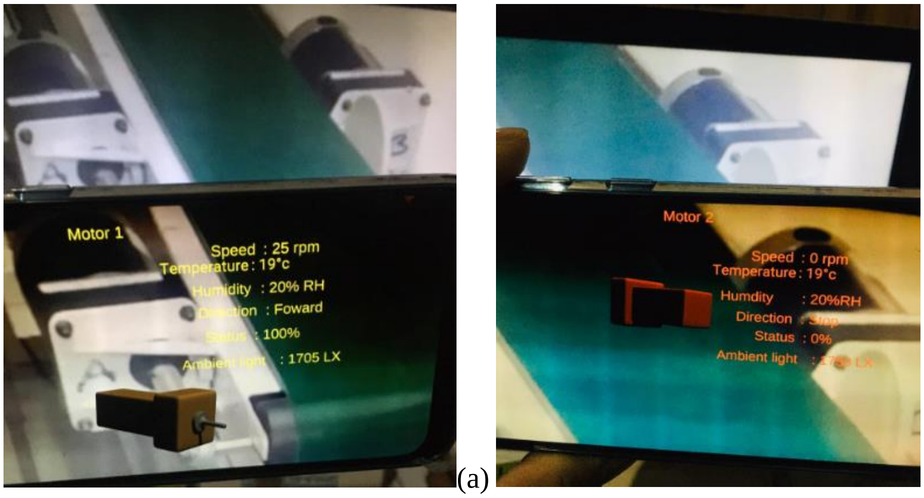
Arm 1

	Arm #	Base Angle	Lower Arm	Upper Arm	Arm Angle	Cripper	Status
	1	0	90	180	0	270	Ok
▸*							

Postion:1,148

Figure 6. Input data on the SCADA system.

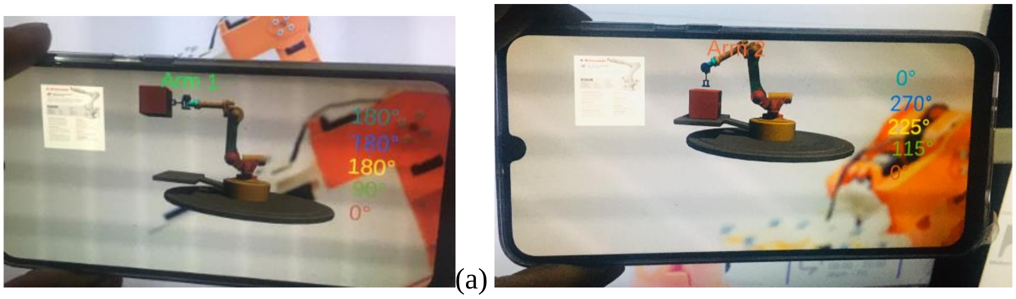
Figure 6 depicts the SCADA system. The system is connected and receives the sensory data every 10ms and the dataset is updated automatically. However, since this is study focused on two motors, the user can select between motor 1 and 2 and the string will automatically be transferred to the AR application. Subsequently, the output results are displayed using two different colours and device numbers to display the augmented data with reference to the device feature and position within the manufacturing environment as indicated in Figures 7 a) and b).



(a) (b)

Figures 7. a) Identification application results for motor 1 using SLAM algorithm; b) Identification application results for motor 2 using SLAM algorithm.

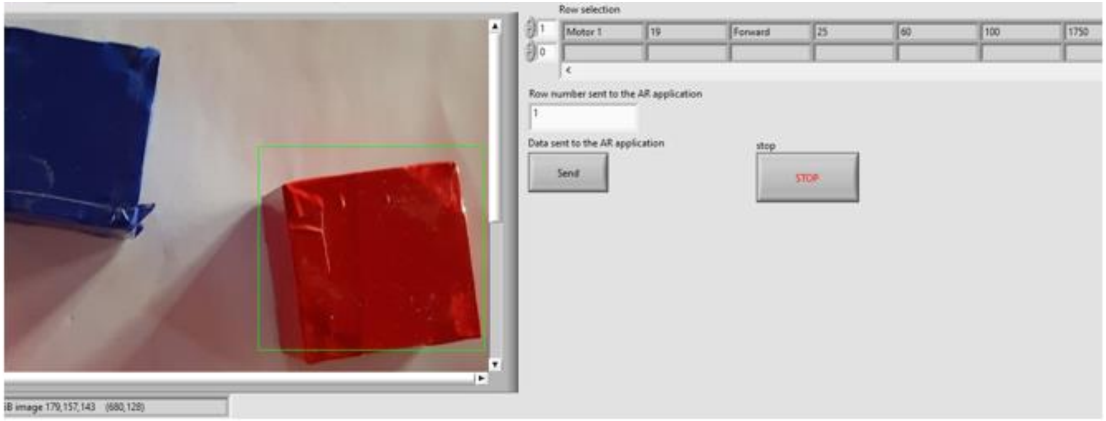
In contrast, the robotic arms we also included for the broader device evaluation scenarios. Figures 8 a) and b) depict the robotic arm evaluation based on their position and features within the smart manufacturing environment. Since the base sample that is used for the application evaluation is not only technical inclined individuals, other elements such as datasheet integration had to be added and embedded onto the application. An additional purpose for this is to also allow for a uniform integrated application that can be augmented (as in Figure 8) as opposed to using a different tool to check for the device operation. The degree turn for every joint is augmented on the side and the joint degree is highlighted by their colour which makes joint identification much easier for users.



(a) (b)

Figure 8 a) Augmented output data based on the identified system; b) Augmented output data based on the unidentified system.

Before the user evaluation survey could be conducted, it was paramount to test the application utilising an industry-rated SCADA system to not only evaluate the user perspective on the application but rather the application efficiency as an industry-rated application. National Instrument™ Labview was utilised as an industry test SCADA system. The results show that the same sensory data can be accurately transferred to the Labview system without any need for alteration provided that the array elements are the same. Figure 9 depicts the SCADA application o the National Instrument™ Labview.



Row selection

1	Motor 1	19	Forward	25	60	100	1750
0							

Row number sent to the AR application: 1

Figure 9 Labview-based SCADA system.

Figure 9 depicts the Labview-based SCADA system for industry-based-test results of the data transfer accuracy between the AR application and the industry-rated SCADA application. The results do show that the SCADA can accurately identify objects based on their color and shape. Furthermore, the received data can be accurately sent to the AR application and has the potential to update data on the correct device and match the SCADA data. Upon completion and successful testing of the AR application on both the motor and robotic arm as well the two SCADAs, as indicated in Figures. (7 (a & b) and 8 (a & b)), and Figure 9, it was important to obtain the user feedback by either sharing the application`s Android Application Package (APK) in a .apk format or sharing a video link. However, due to the constraints of Covid19, a decision was taken to take a video, upload it on YouTube, and share the survey link (Google Forms) and the YouTube link to a controlled number of people (20 users).

The survey comprised of 20 individuals from different backgrounds and disciplines, however, their expertise within the AR environment was not necessarily taken into account but rather their experience in utilising the application. Figure 10 outlines the responses from the 20 people who took part in the survey. is outlined as indicated in Figure 10. The most critical questions and responses are outlined in Figures 10-11.

The results depict that the majority of the sample rates the application good with the initial data being positive from rating 6 to rating 10. However, a balanced sample number is satisfied with the detection, reliability, and datasheet integration, and as a result of the data highlighted in Figure 10, the User Experience (UX) feedback also demonstrates positivity with more than 70% of the sample opting to use the application.

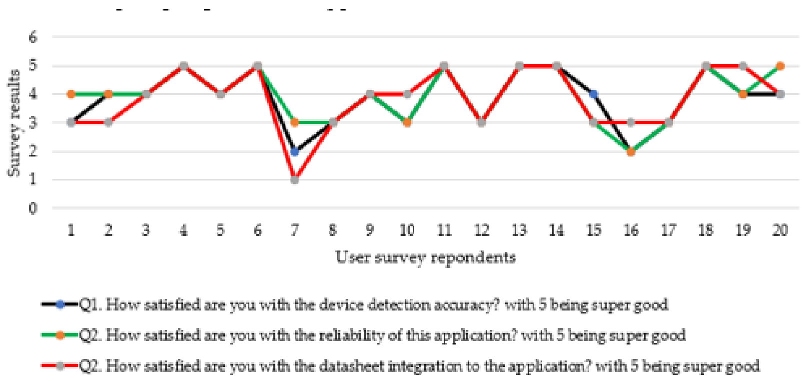


Figure 10. AR Application user experience survey feedback.

As depicted in Figure 10 outlining the UX survey response, the majority of the users, rate this application good, with a minimal number of users not having great confidence in the application detection accuracy. Also, the majority of the users consider the system for adoption citing its reliability and readiness for deployment in an indoor factory setup.

Furthermore, on the reliability question, 65% of the users agree that the AR application is stable, and this is seen when the detection is accomplished by testing the AR application at different angles. However, 30% of the users are comfortable with the reliability and 5% are not satisfied with the application reliability. Subsequently, 35% of the users expressed that the survey surfaced as average with the datasheet integration, while 35% showed satisfaction with datasheet integration. Additionally, 35% might be deemed engineers who know systems and models, and the other 35% are new users of such applications. However, this survey focused on the user experience and as a result, the designation of the user was not factored in. The survey results looking at the user feedback regarding the purchasing and utilisation of the AR application depict that 80% of the users who watched the YouTube video and participated in the survey recommend purchasing the AR application for utilisation in an indoor manufacturing plant.

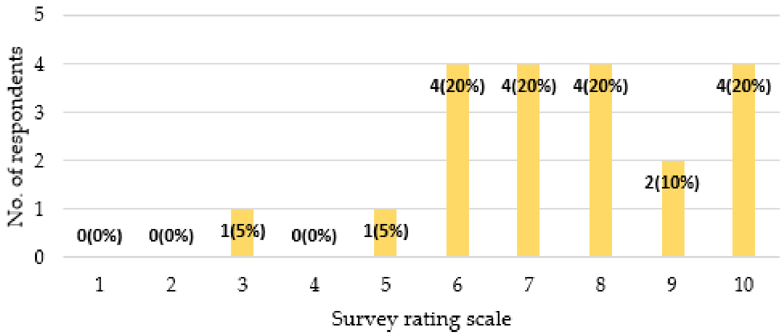


Figure 11. Application rating.

Figure 11 outlines the user rating for the application. 18/20 (90%) of the users rated the application good, with 1 person (5%) rating the application average and another 5% rating the application poor. It is, therefore, seen that the majority (90%) of the users who participated in this survey consider the application useful and needed by the industry to enhance daily manufacturing operations and reduce the time spend on trying to identify the problems within the devices in the manufacturing plant.

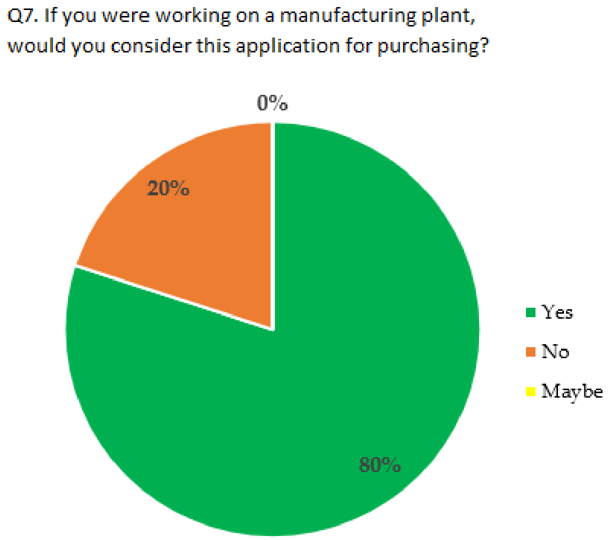


Figure 12. Application purchasing for utilisation in a manufacturing plant.

Figure 12 outline the survey results, looking at the user feedback regarding the AR application. 80% of the users who watched the YouTube video of the operation of the AR application recommended that if they were working at the manufacturing plants, they would purchase the application for use.

4.2. Time-based data acquisition and rendering over the WiFi

To model the application to function as intended, it was necessary to have the input JPEG image sample from the Android camera transferred to the object tracker Unity3D AR database and escort the tracked bounding box onto the preview screen. The sensory data results were then taken and stored in the SQL database and post their storage, they were transferred via the Wemo microcontroller WiFi module through the WiFi connectivity as a string of data packets to the AR application. Furthermore, another system analysis was conducted based on the following scenarios.

The analysis of the two system's run times were as follows, the implementation of the system runtime is based on the size of the data packet transferred from the SCADA system to the AR application. In this context, the SCADA system is acting as the server and the cellphone as the client. Therefore, the client-server connection is a full-duplex connection based on the basic three-way handshake protocol; synchronisation, synchronisation/acknowledgment, and acknowledgment.

Based on the computational time frame interval, the SCADA can detect when a packet has been converted into the binary state (0 or 1) and if it is not transmitted, by not receiving the acknowledgment from the cellphone or AR application and as a result, the SCADA system will continue to transmit data until the connection is disconnected or lost. Subsequently, the data packet transfer rate is measured with 4 samples distance as indicated in Figure 13. The latency test is conducted for the input data transferrable from the SCADA system to the AR application. Subsequently, the latency increases as the distance increases, however, this does not affect the success rate as outlined. Moreover, the data transfer sampling was conducted in the same indoor manufacturing environment for all the samples. However, the external factory variables such as noise, Radio Frequency (RF) interference, etc. were not accounted for in this paper.

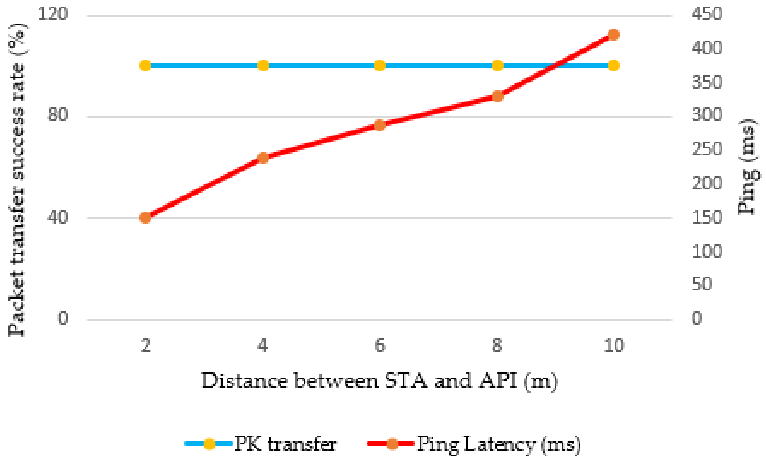


Figure 13. Latency and packet rate success rate results.

Figure 13 is constructed using the SPEED CHECK application on an Android device. The application is used to examine if there is a delay in the WiFi reception and how this would influence the data or transmission speed of the data sent. However, it has been noted that the transmission speed does get affected as a result of the distance, but this does not affect the success rate provided that the WiFi connectivity is still within the accessible range.

4. Conclusion

The aim of this study was to evaluate the user experience for use of augmented reality applications in a Smart Manufacturing plant for device identification and accurate data transfer between developed SCADA system and industry rated-SCADA systems. The results do show that the system accuracy does not require any alteration between different SCADA systems provided that the array elements are the same. In order to achieve and optimally evaluate the application functionality, a testbed had to be developed and tested. Upon successful, testbed development, the AR application was tested, and a video was taken and uploaded on YouTube due to lockdowns that were imposed due to COVID-19 pandemic to enable the target audience to take part in the survey. Following the successful video upload, a survey was developed using Google Forms with 11 questions

In this survey, the findings show that 70% of the users approve of the use of the developed AR application in an industrial setup, 65% of the users are satisfied with the accuracy and reliability of the application and 80% recommend for the adoption and utilisation of this application in an industrial setup.

This paper, therefore, concludes that the majority of the user who participated in the study views this application as a necessary application to optimize the efficiency of fault detection in a Smart Manufacturing environment and recommends the adoption of such an application.

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