DEVELOPMENT OF MOBILE AUGMENTED REALITY TO GUIDE THE ROUNDNESS MEASUREMENT

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ABSTRACT

Roundness measurements are used to measure the cylindrical object, which refers to how closely the shape of the object approaches a perfect circle. Measuring the roundness requires a device that can perform measurements with precision. In this study, a roundness measuring machine is used to check the roundness of the object. However, it is difficult for engineering students to operate the machine as most of them lack the necessary skills and information. A set of questionnaires was distributed to 93 students to determine their level of ability to conduct the roundness measurement using a roundness measuring machine. The result showed that students (89.2%) claimed that they tried to operate the machine correctly but found some parts that were difficult to understand. Therefore, mobile augmented reality (AR) was created to support students in operating the machine. Most students have mobile phones for teaching and personal use. In this study, mobile AR with audio was used to guide the students on how to operate the machine. The effectiveness of mobile AR was then investigated. Thirty students were selected to operate the machine using mobile AR. Results demonstrated that 76.7% of students were satisfied when using the mobile AR for the first time, with no mistakes. The results suggest that mobile AR is effective and useful in engineering measurement.

Keywords: *Roundness measurement, augmented reality, roundness measuring machine*

1.0 INTRODUCTION

Nowadays, the term Augmented Reality (AR) has become more common since its applications are closer to the real than to the virtual world [1]. Indeed, applying AR technologies can improve the learner's motivation and performance. AR environments also offer 3D and, real-time interactivity [2] that have been used for training workers in the manufacturing sector [3], the construction industry [4], industrial maintenance systems [5], and on-site tour guides [6], among others. More recently, AR technology has been used to support the education field [7][8][9][10]. AR is a very efficient technology in higher education. Most researchers [11] have been making an effort to apply mobile AR in higher education fields, including universities and colleges, to improve the learning experience. Hence, students in both education can improve their knowledge and skills, especially on complex theories or mechanism systems or machinery [12]. Mobile AR tool also assists teachers and students in creating an engaging learning environment [13] and creative method of teaching [14]. It is clear that the current mobile AR technologies have a vital impact to e-learning. In fact, the development and improvements within e-learning technique have an important role on ensuring better educational process. Furthermore, if properly used and developed, AR visualisation capabilities can transform education process.

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Mobile AR tool is a mobile software system aiming to provide supportive, e-learning material for students [11][15] through a smartphone. Since most teenagers, especially students in higher learning, have a smartphone with a camera, they can immediately use AR [16]. The mobile learning tools support student learning anytime and can be utilised anywhere. For example, AR technology has been applied for innovative teaching and learning in engineering education [17]. The authors highlighted that AR is expected to improve the learning process, especially for engineering subjects, as they involve laboratory equipment and apparatus. Also, using science education, researchers have examined the potential of AR technology's influence on education [18]. It was then discovered that image-based AR often affords student with spatial ability, practical skills and conceptual understanding and that location-based AR usually supports inquiry-based scientific activities. Besides, AR technology has been designed to enhance practical skills. Andujar et al. [1] developed an image-based AR remote laboratory to show students the use of lab equipment and allow them to interact with the devices.

In another study, the AR in engineering and design application has been experimentally designed to support the teaching of mechanical engineering concepts such as machines, vehicles, platonic solids and tools [19]. The technology allows students to gain knowledge through visuals, increased motivation and thinking skills [20] as it helps the students to easily acquire, process and remember the information. In addition, using AR can improve students' perceptions, knowledge, and interaction with the work and enhance their cognitive ability during learning activities and tasks [11]. Furthermore, AR is extremely beneficial for advanced student learning and versatile learning approaches [21]. The AR technology supports the learning process by aiding students to become familiar with the technology they could use in the future or work in industry [22].

Normally, the measurement of geometric dimension depends on the application of the end product. The measurement of roundness is well-known and commonly used to evaluate and control the quality of cylindrical objects [23]. Roundness is among the important parameters in machined product performance and life [24]. This parameter affects the product safety, functionality and assembly. In other words, the roundness measurement is a critical part of the quality assurance process.

New technology in machines and software in product measurement and inspection allows for faster and more accurate. However, the roundness measurement process cannot be rushed, or the quality of the product will be damaged. Roundness measurement machines have a stylus probe that physically touches the product. Using the machine, this process helps to increase the level of precision and accuracy, which can save time, and potentially reduce human error and improve quality control. Human error will always be a factor in metrology laboratories since the students do not have the skills to conduct the machine. Sometimes, they need to refer to the manual or standard procedure with limited information. Therefore, some of them fail to understand the operation of the machine. Some students may have difficulty using the machine by merely reading the instructions, while some others face difficulty visualizing the instructions, causing them to fail or misuse the system. Furthermore, errors that occur while conducting the machine could also be the main issue, as students might find it difficult to get accurate results since the machine procedure is not performed well. However, the key challenge is that no matter how complex the machine product is, the students must be able to operate the machine properly to take roundness measurements. Therefore, it is apparent that the use of mobile Augmented Reality (AR) should be implemented to solve such problems. The benefits of AR technology are that the same physical laboratory settings can be used for different experiments [1]. Besides, mobile AR can assist individuals with special needs in their skill development process and help them become more independent [25]. This gap has become the main objective of this study, which is to develop an interactive mobile AR for engineering students to operate a roundness measuring machine.

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2.0 METHODOLOGY

The survey and observation were done on the engineering students to gather the information and user requirements. A set of questionnaire surveys were distributed, which consisted of their personal experience and questions relating to their perception and responses to conduct the roundness measurement. The overview of this case study also was introduced, and their feedback was used for analysis purposes. Basically, the purpose of the questionnaire is to determine students' understanding and ability to operate the roundness measuring machine and collect their feedback and opinions about AR technology. The questionnaire included 12 questions specifically designed to obtain information about the users' ability to operate the machine, their understanding of the machine's procedural standard and their perception of AR technology.

Figure 1 presents the roundness measuring machine in the metrology laboratory. The roundness measuring machine comprises a high-precision rotary machine, displacement sensors and a computer system [26]. The measurement method used was rotational datum. The most accurate method for determining the roundness of a component is to use a scanning probe to measure the variation of radius from an accurate rotational datum (one that remains in contact with the surface and collects high density data points). The data can then be fitted with a circle, while the roundness is calculated using knowledge of the component centre. There are numerous dedicated roundness measuring instruments available. The most common setup is a system with a rotating table on which the component is mounted. A gauge is mounted on a radial arm that can be adjusted to make contact with the component. The arm is mounted on a column that allows the measurement plane's height to be adjusted. Such instruments' linear axes are frequently motorised and have a high form of accuracy, allowing the instrument to be used to measure other parameters such as flatness, straightness, and cylindricity. In addition, several errors can occur while conducting this roundness measuring machine. The high risk of getting errors is when the users run the centering procedure which must be wisely performed to obtain an accurate result. In conducting the centering process, the users need to adjust the tilt knob attached the rotary table. Failing to centre the workpiece can cause errors in the result. Besides, insufficient air pressure can also affect the roundness measurement. The suitable air pressure is not less than 4 bars; otherwise, the machine cannot be run.

Figure 1: Roundness measuring machine

Figure 2 shows the basic steps involved in developing mobile AR for roundness measurement. Through AR, users can interact with virtual objects as if the real objects are in front of them. At the initial stage, the components of the roundness measuringmachine were created by Fusion 360. Fusion 360 is the most modern Autodesk product essential for product design and development. The user-friendly Fusion 360 software was employed to build the 3D model of the roundness measuring machine. All the components need to be assembled to

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create a 3D model of a roundness measuring machine.

Creating the image target is essential when developing augmented reality technology. The 3D model of the roundness measuring machine will be displayed on the Quick Response (QR) code, a 2D matrix code that can be easily read by a digital device [27]. The reason behind the use of the QR code is that there is no limited scan-life, and it does not expire. For the time being, smartphones have become a part of every person's life. The mobile smartphone can be used to scan the QR code. In this case study, the Android smartphone can be used to scan the QR code. The use of QR codes in teaching has been increasing and has become more effective by offering teaching clips, e-textbooks and AR experiments [28].

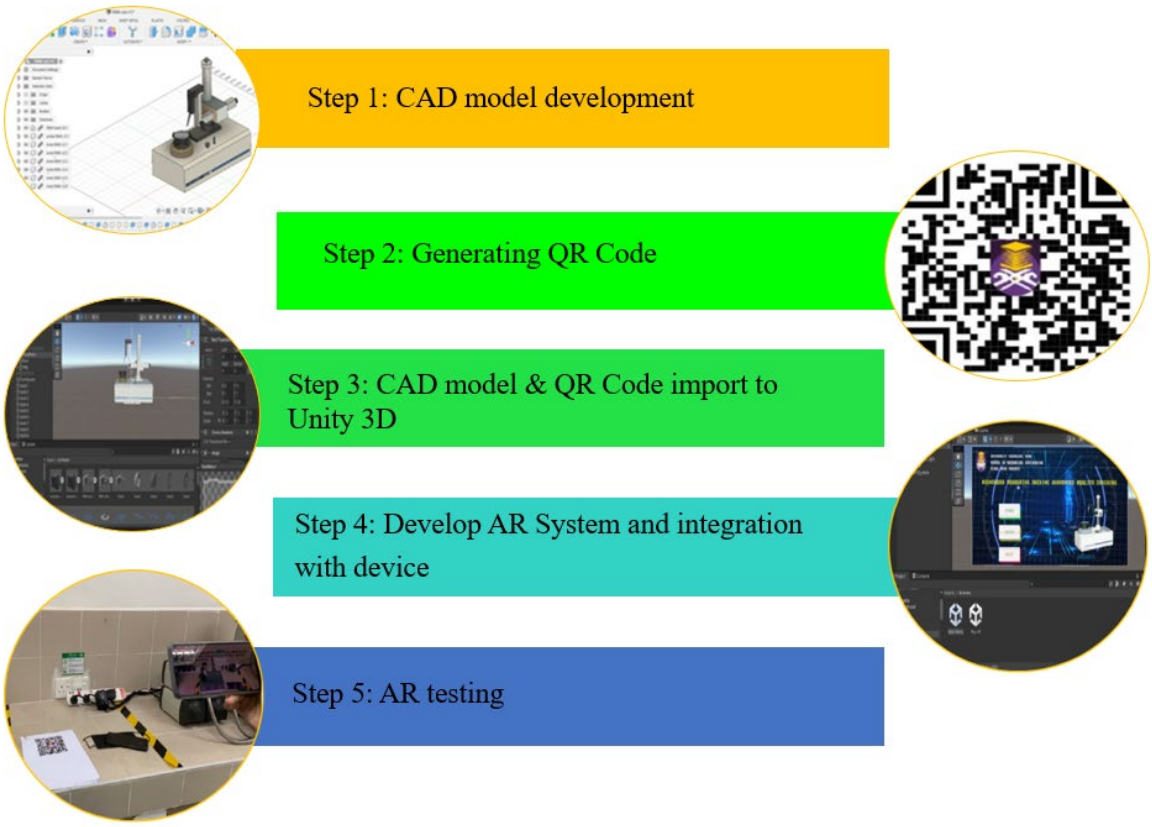

Figure 2: Development of mobile AR for roundness measurement

Figure 3 shows the AR user interface of the roundness measuring machine. The main menu interface consists of three buttons labelled "START", "ABOUT", and "EXIT". Clicking the "START" button will take users to the next scene, where they need to scan the QR Code. When the users are done with the augmented reality experience, they may press a "Quit" button to exit the app. In this mobile AR, users can learn about the machine components and how to operate the machine.

Figure 3: AR user interface

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Finally, once the AR system's application has been built and completed, it must be tested to ensure its function as intended and measure its performance. In order to test the performance of mobile AR technology, users need to download the APK file that has been given. The camera needs a sharp and clear view of the QR code before it can read it. If the QR code is illegible or difficult to read, the augmented reality software will be unable to recognise the image target. Figure 4 displays the testing of mobile AR technology.

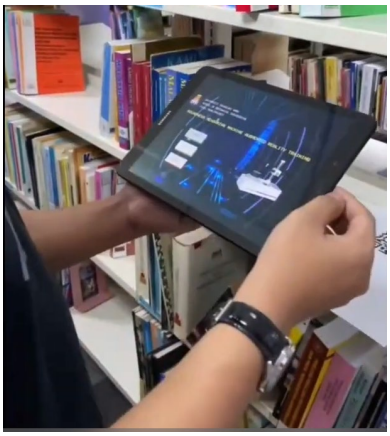

Figure 4: Testing of mobile AR technology

3.0 RESULTS AND DISCUSSION

This questionnaire was distributed to undergraduate students, comprising diploma and bachelor students of mechanical engineering. A total of 93 questionnaires were used for further analysis. Based on the survey, 69 (74.2%) of participants were diploma students, 24 (35.8%) were bachelor students. Specifically, 22 women (23.7%) and 71 men (76.3%) between 20-23 years responded to the questionnaire. Most participants have experience in conducting the roundness measurement. Additionally, most of them used the machine for laboratory measurement (experiment) to measure the roundness of the circular cross-section of a shaft or circular cone.

The first section of the questionnaire aimed at gathering information to determine the level of the respondent's ability to conduct the roundness measurement using a roundness measuring machine. Figures 3 and 4 illustrate the responses regarding their awareness of operating the roundness measuring machine. The awareness questions were designed to check the ability and understanding of roundness measurement operation. Based on Figure 5, almost 89.2% (83) of respondents claimed that they tried to operate the machine correctly but found that some parts were difficult to understand. Therefore, they need guidance from technical staff when operating the machine to take roundness measurements. Referring to Figure 6, more than 90% answered that they were unsure of the machine procedure.

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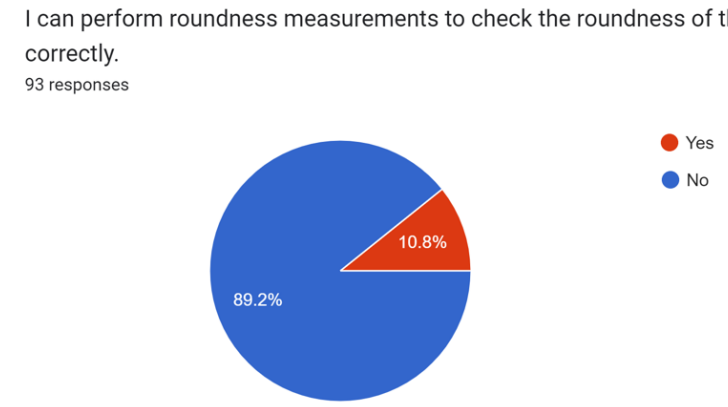

Figure 5: Response to question: Ability to conduct the roundness measuring machine

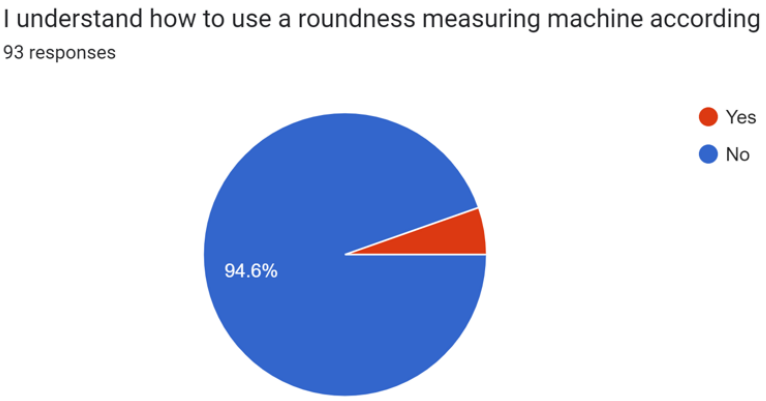

Figure 6: Response to question: Understanding the machine procedural standard

In addition, this survey is needed to identify whether the students realised the function and usefulness of each machine component. The survey results showed that most of the students, 73 (78.5%), did not fully understand the functionality of each machine component. The students claimed that they only recognised a few important parts, like the measuring probe. Some of them knew the function of the components but did not know the names of the components.

The second section of the questionnaire is to examine the student's knowledge and perspective on the use of mobile AR technology in the engineering measurement. Based on the resulting survey, some of the respondents, 25 (26.9%), said they had experienced and used the AR technology, while the other respondents, 68 (73.1%), claimed they did not use or tried any AR applications.

Table 1. Summary of survey responses

Questions	Yes	No
Ability to conducting the roundness measuring machine	10 (10.8%)	83 (89.2%)
Understanding the machine procedural standard	5 (5.4%)	88 (94.6%)
Usefulness of machine components	20 (21.5%)	73 (78.5%)
Knowledge of AR application	25 (26.9%)	68 (73.1%)

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Students were provided with a QR code. Figure 7 shows the provided QR code. Students need to scan the QR code to collect information about the roundness measuring machine, including all information about the procedures, components and functions of the machine, which can and cannot be provided. This mobile AR system provides audio and text. Therefore, it helps students understand the concept of operating a circular measuring machine accurately. Mobile AR with audio in operating roundness measuring was used in this study.

Figure 7: Scanning QR code

A total of 30 students used mobile AR with audio to investigate the effectiveness and its performance towards the teaching process in conducting the roundness measurement. Most of the students used the Android smartphone to conduct the experiment analysis. In this experiment, the student's ability was measured in terms of the time required to conduct the roundness measurement and without error. Figure 8 shows the students conducting roundness measuring machines using mobile AR with audio. The mobile AR system with audio showed that learning could be faster and more efficient as the students managed to operate the machine with less time consumption and minimum errors made. In this system, the students need to hear the procedure while conducting the machine. These techniques considerably improved the participants' capacity to understand the guidance offered by the AR application. Based on the investigation, 76.7% of students were satisfied when using the mobile AR with audio for the first time and no mistake. The results showed that the mobile AR with audio was effective and useful in engineering measurement.

Figure 8: Conducting roundness measuring machine with mobile AR

A survey link was distributed to students to obtain feedback on the usage of mobile AR with audio in operating roundness measuring machine. Figure 9 illustrates the feedback from the students, where most of them were positive. One of the most important feedback was that it was easy to understand the procedure. Good voice quality and explanation could be a reason the AR system with audio was chosen as the best and most interactive learning. It also can minimise the mistakes

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made in conducting the machine. AR system with audio was effective in helping the students understand the procedure.

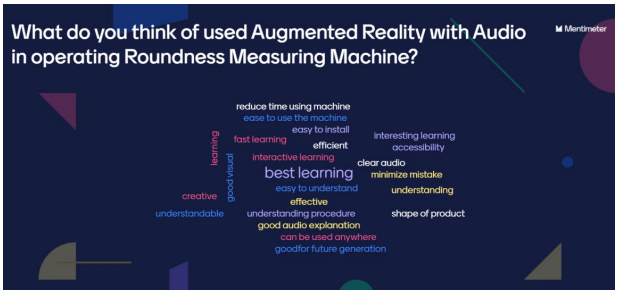

Figure 9: Student feedback

4.0 CONCLUSION

According to the results of the analysis, most students find it difficult to conduct the roundness measuring machine and need guidance from technical staff. The students were unable to operate the machine properly according to the standard of procedure. In this study, mobile AR technology was used to train students to learn how to conduct the roundness measuring machine. Based on the investigation, 76.7% of students were satisfied when using the mobile AR with audio for the first time and no mistakes were made. In terms of student perception, mobile AR could lead to an increased ability in operating the roundness measuring machine properly.

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