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The design and performance of QR-based recognition software for distribution station components

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ABSTRACT

This study aims to determine the design and performance of Recognition Software for Distribution Station Components based on the Quick Response Code (QR-code) for the Flexible Manufacturing System Laboratory Work. This study uses a Research and Development (R&D) method based on Modified Waterfall Model from the Systems Development Life Cycle (SDLC). The development stages consist of Requirements Analysis and Definition, System and Software Design, Implementation and Unit Testing, Integration and System Testing, and Operation and Maintenance. The functional suitability test yielded excellent results, scoring 100%. Similarly, the compatibility test achieved a high score of 95%. The interaction capability test also performed well, scoring 85.56%. Additionally, the performance efficiency test showed impressive results, averaging 0.026 seconds per frame with an average of 7% CPU and 279 Mb memory resource utilization. The overall quality and performance of the D-Static application are very suitable for use as a Distributing Station components recognition application based on QR-Code for the Flexible Manufacturing System Laboratory Work.

Keywords: components recognition, flexible manufacturing system laboratory, qr-code

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INTRODUCTION

The industry is a unified link in which there is a process of processing raw materials into a product that will be marketed to consumers. Activities in the industry are not only the buying and selling process like in the market, but many things are involved in it such as suppliers, distributors, consumers, and the production process either done by machine or by human power (León et al., 2018). Along with the development of human civilization, industrial changes are also increasing day by day. The journey of industrial change takes place very quickly, where the production process that was previously done by humans is now fully carried out by machines (Suwardana, 2018). The industry continued to progress until slowly the introduction of Industry 5.0 with the concept of empowering people, technology, and data. The industry does not only process raw materials using machines but also blends manufacturing technology, artificial intelligence, big data, and IoT (Russmann et al., 2015).

Mechatronic engineering is a branch of engineering that will be very much needed in the 21st century. According to the 2020 Future of Job Survey by the World Economic Forum, Process Automation Specialist jobs are among the top 10 jobs that will shine by 2025 (Brown et al., 2020). The high level of need for Mechatronic Engineering graduates in the world of work makes a Mechatronic Engineering graduate required to master the knowledge and skills to answer future challenges.

One of the productive courses that are closely related to the competence of Mechatronic Engineering graduates is the Flexible Manufacturing System lab work. In general, Flexible Manufacturing System (FMS) is a type of production system that applies the concept of automation at its workstation (Setiawan et al., 2015). FMS is designed to easily adapt to changes in the type and quantity of products produced. By using an FMS, factories and industries can increase production efficiency significantly while lowering overall production costs. Apart from that, FMS also plays an important role in the make-to-order strategy where it can adapt to customer needs (Yadav & Jayswal, 2018).

Practical activities in Flexible Manufacturing System lab work include students identifying components and equipment, analyzing processes on systems, making system designs, and program systems that have been designed. The Manufacturing System Trainer used in this course is the Modular Production System (MPS) 500 which consists of several stations. One of the stations used for learning activities is the Distributing Station. The activities for identifying components at the Distributing Station are currently still using lab sheets and manuals.

Quick Response Code (QR-Code) is a type of matrix barcode that can store data in the form of contacts, e-mails, phone numbers, URLs, and other information (Muhammad Priyono Tri S, 2015). QR codes used to be used to track vehicle parts in the manufacturing industry, along with their development. QR-code were used for the first time in Japan's automotive industry and have four types of data standards consisting of numeric, alphanumeric, binary, and kanji (Kucirkova et al., 2016) (N. Kucirkova et al., 2016). QR codes are now used for various purposes, one of which is to facilitate the tracking of goods or objects using a smartphone (Priyambodo et al., 2020).

Almost all students today always carry and use their smartphones during lecture activities. The operating system used on their smartphones is mostly Android. Arifianto also explained that Android is a Linux-based operating system designed for smartphones (Arifianto, 2011). It is growing and evolving alongside other operating systems like Iphone Operating System (IOS), Symbian, and Windows Mobile (Hermawan, 2011). The Android operating system market share in Indonesia ranks first with a percentage of 89.04% (Statcounter, 2024). The Android operating system is popular among the public because it is open source and easy to develop to create various kinds of applications (Safaat, 2012).

Learning media is defined as a tool that can help the learning process teaching so that it can achieve learning goals better and more perfectly (Cecep Kustandi & Dr. Daddy Darmawan, 2020). Using learning media will help to stimulate students' minds, feelings, interests, and students' attention in the learning process (Mashuri, 2019). Utilizing Android applications as a learning medium is a good combination because it can attract student interest and improve the quality of learning in the Flexible Manufacturing System Practice course.

Incorporating QR-code into learning has been demonstrated to yield positive effects, as evidenced by the levels of acceptance and satisfaction among industrial engineering students (Torres-Jiménez et al., 2018). Similarly, the use of QR codes combined with multimedia video content also yields increased interest, achievement, and understanding among students enrolled in engineering economy courses (Ahmed & Zaneldin, 2020). The utilization of QR codes in educational development is considered familiar among students due to its easy usage, possessing visual appeal, both when presenting shallow or in-depth content (Sondhi & Kumar, 2022).

Application development as a learning medium will be in vain if the developed application has problems when used. Application testing needs to be done to ensure the quality and performance of the software. Software testing there are various kinds of testing standards. The testing in this study uses the ISO/IEC 25010 standard. The scope of quality testing using this standard includes specification and evaluation using perspectives that include functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, flexibility, and safety. The characteristics and sub-characteristics of this test provide consistent terminology for determining, measuring, and evaluating software quality (ISO/IEC 25010, 2022).

Based on this description, the researchers tried to develop a Distributing Station Components (D-Static) application with the help of a QR-Code. This study aims to determine the design and performance of the QR-Code-assisted D-Static application for the Flexible Manufacturing System Practice course based on engineering design processes of the ISO 25010 standard which can facilitate students in understanding the components comprising the distribution station in more detail, as a form of utilizing information technology in the field of education.

METHOD

This research uses the Research and Development (R&D) method based on the Waterfall Model-based Systems Development Life Cycle (SDLC). Educational Research and development (R&D) are a process used to develop and validate educational products (Gall et al., 1996). This development stage consists of Requirements Analysis and Definition, System and Software Design, Implementation and Unit Testing, Integration and System Testing, and Operation and Maintenance (Sommerville, 2016).

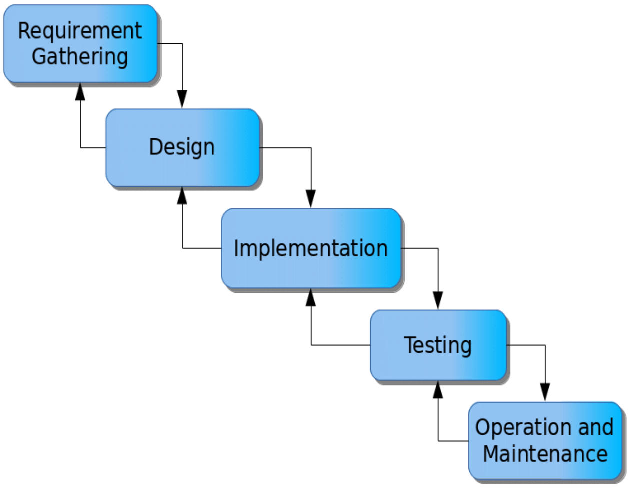

Figure 1. Modified Waterfall Model

Requirements Analysis and Definition (needs analysis and definition) is the initial stage of development which aims to produce a minimum specification of the product being developed and perform a requirements analysis (Simplilearn, 2023). The system and software design is then designed at the System and Software Design stage. System and software design consists of Unified Modeling Language (UML) design and User Interface (UI) design. The system design and software that have been designed are then implemented at the Implementation and Unit Testing stage. Each unit that has been implemented is carried out unit testing to find out whether there are still errors or not. The units that have been tested are then integrated into a system and system testing is carried out at the Integration and System Testing stage. The system that has been tested is then disseminated to users at the Operation and Maintenance stage.

This research is a development activity carried out individually which consists of several activities ranging from conducting field observations, creating a QR-Code-assisted D-Static application, and testing the performance of the resulting application based on the ISO/IEC 25010:2011 standard. The test is carried out based on Assaf Ben David's theory which consists of several characteristics including functional suitability, compatibility, usability, and performance efficiency (David, 2011).

Data collection techniques using the method of observation and questionnaires. Functional suitability and usability tests have been done by giving test questionnaires to the test subjects. The trial subjects of this research were students and lecturers of the Department of Electrical Engineering Education. Compatibility testing is carried out by testing the application together with other applications (multi-tasking) on one device and testing applications on various Operating Systems (OS) and device types. Meanwhile, in testing the performance efficiency of the application, testing was carried out with the Apptim software.

The data collection instruments used in this study consisted of functional suitability, usability, and compatibility testing instruments. The data analysis technique was carried out using the following formula calculation:

$$Score\ (\%) = \frac{Score\ Earned}{Maximum\ Score} \times 100\%$$

The results of the calculation of the percentage of feasibility obtained are then converted into the following table 1 to determine the level of product feasibility (Sudaryono, 2015).

Table 1. Score Interpretation

No	Percentage	Interpretation
1.	0 – 20 %	Very Indecent
2.	21 – 40 %	Indecent
3.	41 – 60 %	Decent enough
4.	61 – 80 %	Decent
5.	81 – 100 %	Very Decent

RESULTS AND DISCUSSION

Software development consists of several stages, namely Requirement Analysis and Definition, System and Software Design, Implementation and Unit Testing, Integration and System Testing, and Operation and Maintenance (I. Sommerville, 2016). The initial stage of development, namely Requirements Analysis and Definition, produces a minimum specification of the product developed, namely the Distributing Station Components (D-Static) Application with the main feature of Scanning QR-Code components. Application development uses Android Studio's Integrated Development Environment (IDE) and is distributed to users via the Google Play Store.

The second stage of development, namely System and Software Design, produces UML designs (Use Case Diagrams, Sequence Diagrams, and Activity Diagrams) and UI designs. The following are the results of the design at the System and Software Design stage. Use Case Diagrams are used to represent the dynamic behavior of a system that describes actors, use cases, and the relationship between them. The actor in the application use case diagram design is the application user, namely the student of the Department of Electrical Engineering Education. While the use case is an interaction between actors and the system that represents a simple sequence of steps. The use case diagram design for the D-Static application can be seen in Figure 2.

Figure 2. Use Case Diagram Plan

A sequence diagram is a diagram that displays the interaction and collaboration between objects in two dimensions so that it can be seen how an operation is carried out. While the activity diagram is a diagram that describes all the processes that occur in the system. An activity diagram is the development of a use case that displays the flow of activity in the form of a sequence of processes or workflows on the D-Static application system. Figure 3 and Figure 4 below are the design of the sequence diagram and activity diagram for scanning component QR codes.

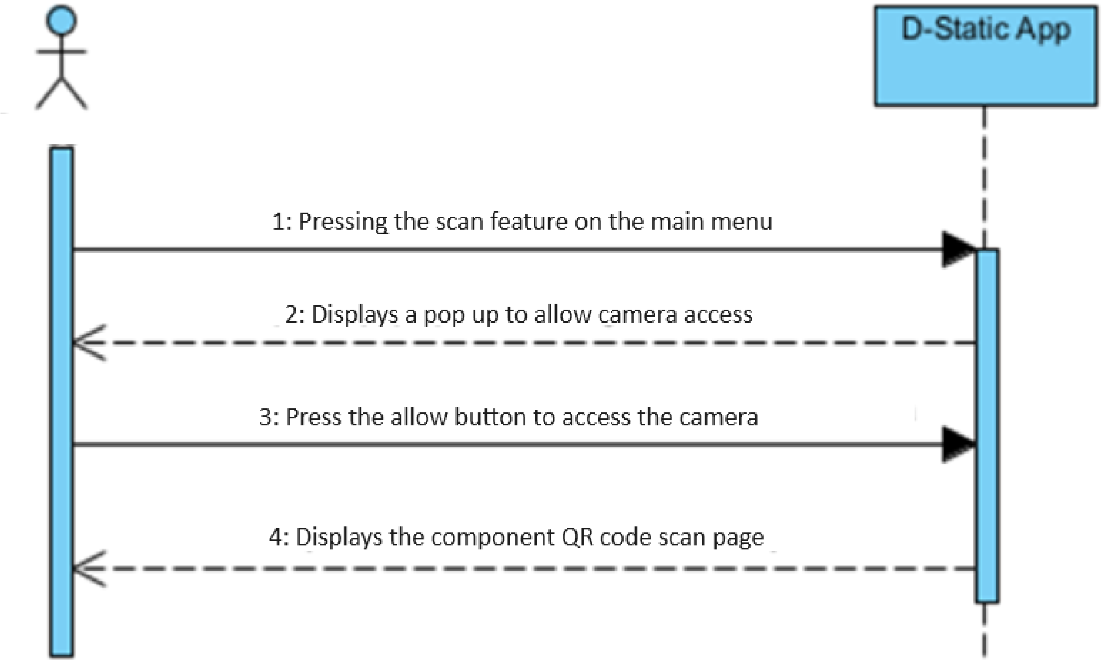

Figure 3. Sequence Diagram Plan

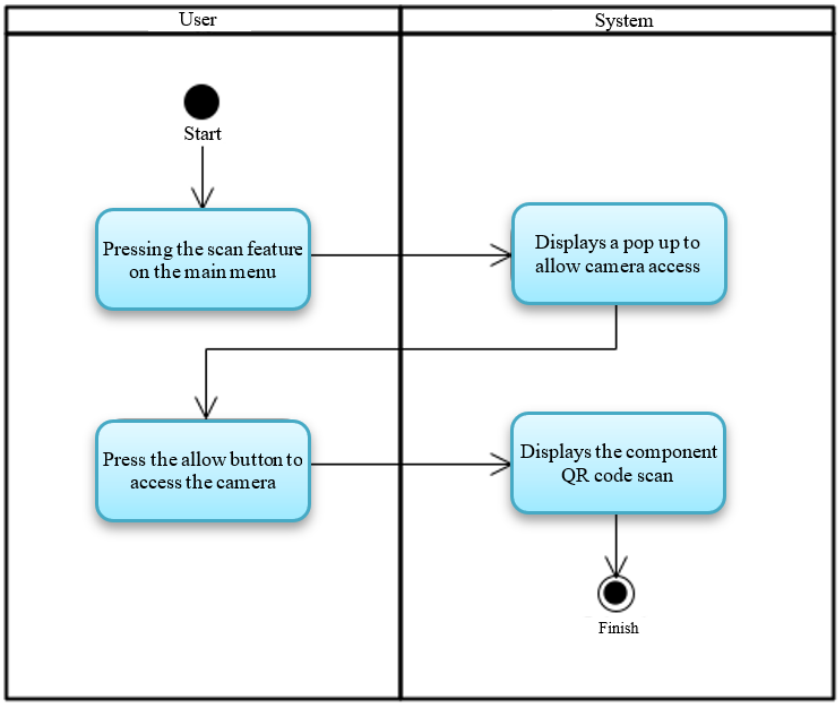

Figure 4. Activity Diagram Plan

The user interface (UI) is a visual display of software that is used as a bridge between the system and its users. The UI displayed is in the form of shapes, colors, and text so that the software developed is more attractive when used. The UI display is designed with several aspects ranging from layout, logo, color selection, easy-to-read typography, and other aspects that aim to beautify the appearance of the software. The UI design in this study will be designed using Adobe XD software. Figure 5 below is an example of the resulting UI design.

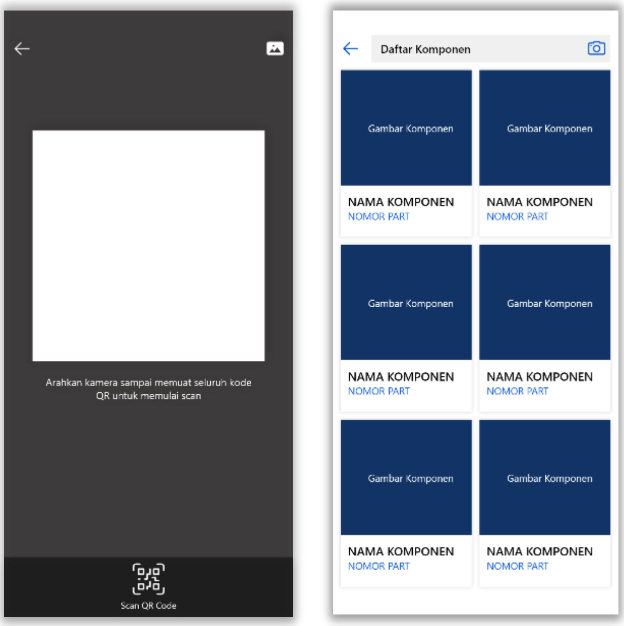

Figure 5. User Interface Design Plan

The system design and software that have been designed are then implemented using the Integrated Development Environment (IDE) Android Studio. The Android Studio IDE comes with the Android SDK and Gradle. The implementation stage consists of layout implementation and programming implementation. The implementation of the application layout is the implementation stage of the User Interface (UI) design which was previously designed with Adobe XD software. The application layout implementation is designed with android studio software with the Extensible Markup Language (XML) programming language. While the programming implementation is the coding stage or programming of the D-Static application. This stage aims to program the application so that the application can run according to the previously designed UML design. The languages used in the programming implementation are the Java and Kotlin programming languages. Figure 6 below is the result of the implementation of the layout in the D-Static application.

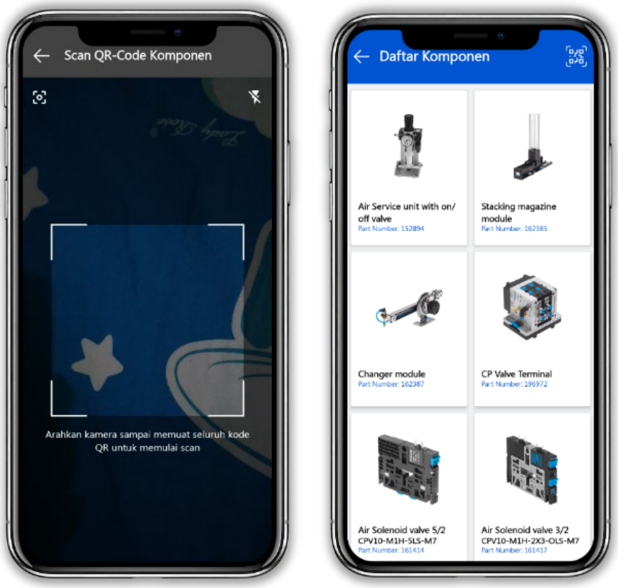

Figure 6. The Result of Layout Implementation

The unit testing stage is carried out by application debugging. Application debugging is the process of running applications that have been programmed to find out whether the program is appropriate or if there are still errors in each unit. This stage is very important to do to find out whether the functions on each application page are running well or not. Application debugging is done in 2 ways, namely through the Android Virtual Device (AVD) Manager and by using USB Debugging via a smartphone.

Each unit that has been tested is then integrated into a system and system testing is carried out. System testing is carried out based on the ISO/IEC 25010 standard. The testing characteristics refer to several benchmarks in the ISO/IEC 25010 standard, namely functional suitability, compatibility, interaction capability, and performance efficiency. Functional suitability testing is divided into several sub characteristics including functional completeness, functional correctness, and functional appropriateness. Functional suitability testing was carried out by 2 lecturers of the Department of Electrical Engineering Education who understood the software development process. The results of the functional suitability test can be seen in Table 2.

Table 2. Functional suitability test results

No	Characteristics	Earned Score	Max Score
1.	Functional Completeness	16	16
2.	Functional Correctness	20	20
3.	Functional Appropriateness	6	6
	Total	42	42

Based on the results of the functional suitability test in table 2, the percentage of eligibility can be calculated as follows.

$$Score\ (\%) = \frac{Earned\ Score}{Maximum\ Score}\ x\ 100\% = \frac{42}{42}\ x\ 100\% = 100\%$$

The functional suitability test got a score of 42 out of 42 with a percentage score of 100%. Based on the interpretation of the scores in table 1, it can be concluded that the quality of the D-Static application is in the "Very Decent" category based on the characteristics of the functional suitability test.

Compatibility testing is divided into several sub-characteristics of testing including co-existence testing and interoperability testing. Compatibility testing is done by testing the use of the application in conjunction with other applications (multi-tasking) on one Android device. The results of co-existence testing on 15 frequently used applications get a score of 15 out of a maximum score of 15 with a percentage score of 100%. These results explain that the D-Static application can multi-task with other applications on one device without disturbing the performance of the application.

Compatibility testing on sub-characteristics of interoperability testing is carried out through the Test Lab menu on Google Firebase. Tests were carried out on 25 android devices, both virtual and physical devices with various operating systems, device types, and screen sizes. The test results obtained a score of 23 out of 25 with a percentage score of 92%. These results explain that the D-Static application can run well on various OS and device types ranging from Android Kitkat OS to Android R. Tests conducted on the Google Play Store also show that the D-Static application supports at least 15,745 Android devices currently available.

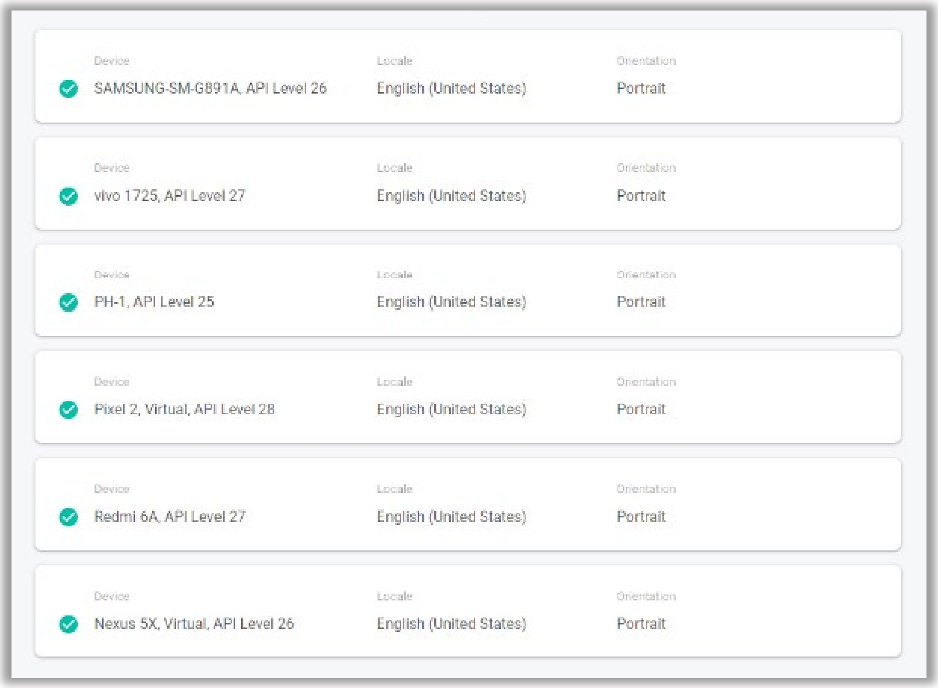

Figure 7. Compatibility Testing Using Google Firebase Test Lab

Interaction capability is divided into several sub-characteristics of the test, namely appropriateness recognizability, operability, learnability, and self-descriptiveness. The test was carried out by 30 respondents consisting of 2 lecturers of the Department of Electrical Engineering Education and 28 students of the Department of Electrical Engineering Education. The results of usability testing can be seen in Table 3.

Table 3. Usability Tests Results

No	Sub Characteristic	Earned Score	Max Score
1.	Appropriateness recognizability	825	976
2.	Operability	1054	1220
3.	Learnability	416	488
4.	Self-descriptiveness	732	854
	Total	3027	3538

Based on the interaction capability test in Table 3, it can be calculated accordingly as follows.

$$Score\ (\%) = \frac{Earned\ Score}{Maximum\ Score}\ x\ 100\% = \frac{3027}{3538}\ x\ 100\% = \ 85.56\%$$

The interaction capability test results obtained a score of 3027 from a maximum score of 3538 with a feasibility percentage of 85.56%. Based on the interpretation of the scores in table 1, the D-Static application is categorized as "Very Decent" on the characteristics of usability testing.

Performance efficiency testing is divided into sub-characteristics of testing, namely time behavior, resource utilization, and capacity. Performance efficiency testing is carried out using the Apptim software. The test is carried out by connecting a smartphone that has the D-Static application installed with a Personal Computer (PC) that has the Apptim software installed using the Universal Serial Bus (USB). Figure 8 is the result of performance efficiency testing using Apptim software.

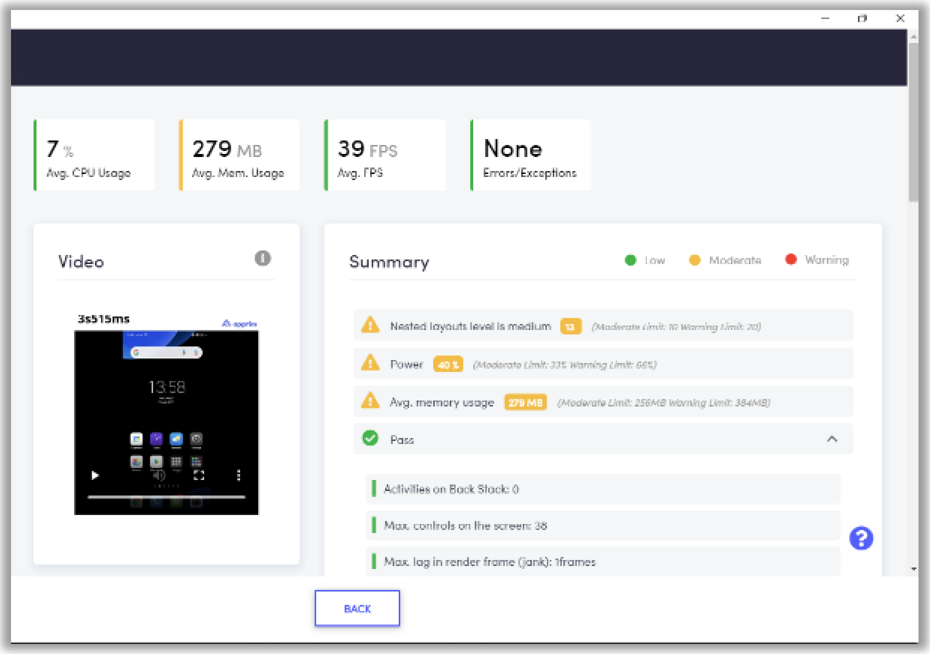

Figure 8. Performance Efficiency Test using Apptim Software

The frame rate of the D-Static application based on the performance efficiency test results in Figure 8 is 39 frame/second (FPS). The FPS test indicator in Figure 8 is green, which means the D-Static application is low risk (low risk). Application time behavior can be calculated by the following formula.

$$Time\ behavior = \frac{1}{Avv.FPS}\ x\ 100\% = \frac{1}{39}\ x\ 100\% = \ 0.026\ second/frame$$

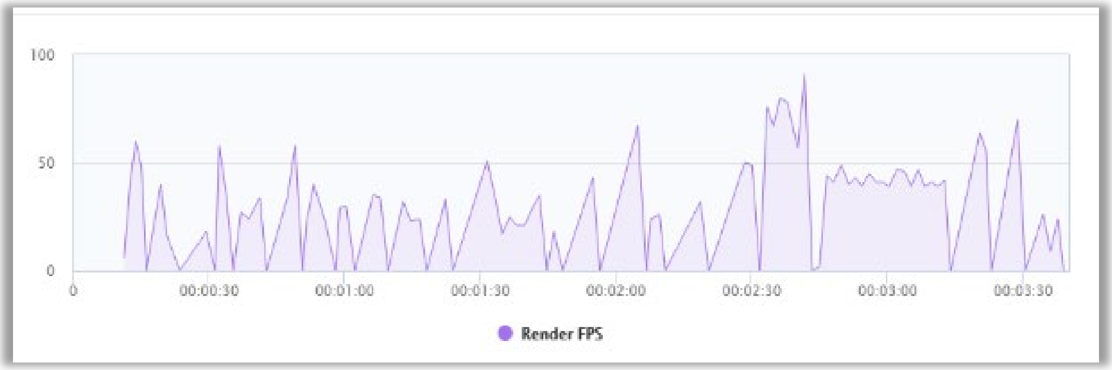

Figure 9. D-Static App Rendering Graphics

Resource utilization is calculated by taking a test sample and then averaging it. Based on the results of the performance efficiency test in Figure 8, the average CPU usage in the D-Static application is 7%. These results explain that the average processing time to run each thread is 70ms. The CPU usage indicator in the image is also green which means it has a low risk.

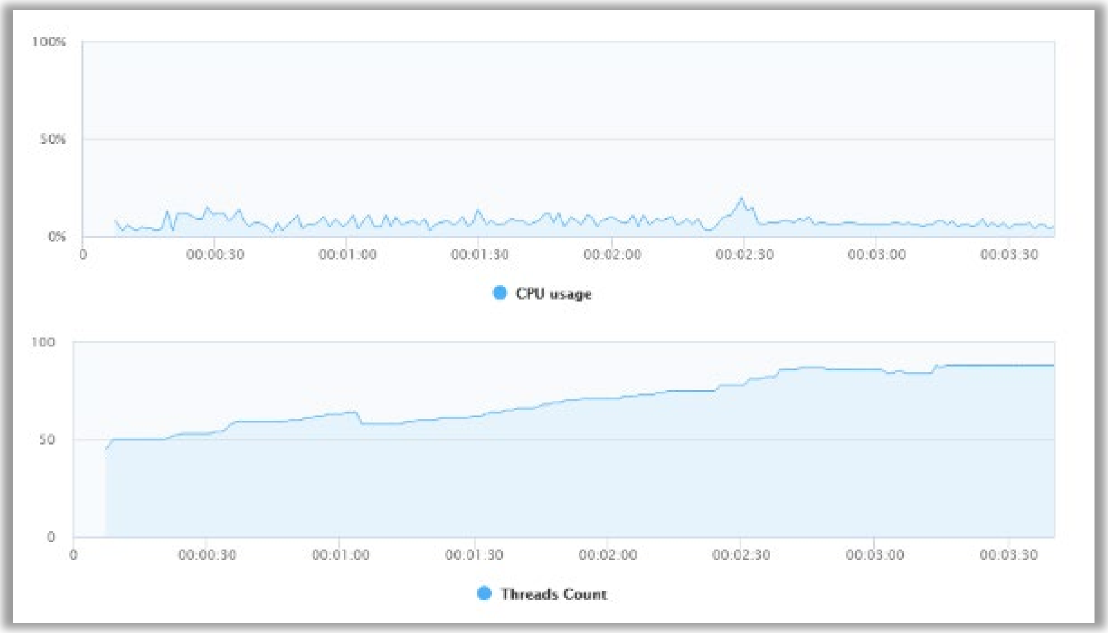

Figure 10. D-Static App CPU Usage Graph

Capacity of storage resources is D-Static application based on the test results in Figure 8 is 279 Mb (Megabytes). The Memory resource utilization test indicator is yellow, which means moderate risk. The maximum limit for low-risk memory resource utilization is 256 MB, while the minimum warning risk memory resource utilization limit is 384 MB. Although memory resource utilization is in the moderate risk category, the results are still closer to the low-risk category than warning risk so that application performance can still run well and smoothly.

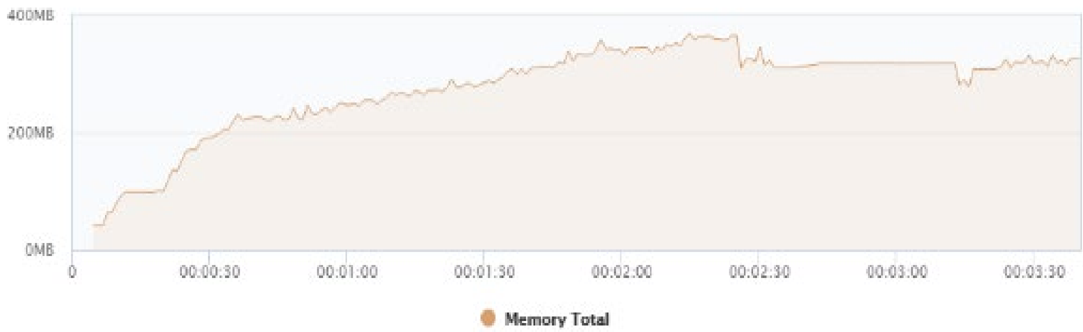

Figure 11. D-Static Application Memory Usage Graph

Based on all the results of the performance efficiency test, it can be concluded that the D-Static application runs well and smoothly and there are no obstacles that make the application launch fail and force close. Therefore, the D-Static application can be categorized as "Very Eligible" on the characteristics of performance efficiency testing.

The last stage of D-Static application development is Operation and maintenance where the application is disseminated to users and system maintenance are carried out. Deployment is done by uploading the application to the Google Play Store through the Google Play Console. The project that has been created is then maintained by doing a push to Github via Git. This storage is for code versioning and project management. So that if new features and functions are added, the project can be easily improved and developed. Although D-Static application development is very good, it still has some limitations. The D-Static application developed is based on Android and is not developed on IOS-based smartphone devices. The application also only introduces components on the MPS 500 Distributing Station. The application also requires an internet connection to get full application features such as viewing images and playing videos.

CONCLUSION

The component recognition application developed is called D-Static with the main feature of Scan QR Code. The test is carried out based on the ISO/IEC 25010 standard which consists of several test characteristics, namely functional suitability, compatibility, interaction capability, and performance efficiency. The results of the functional suitability test are in the very decent category with a percentage score of 100%. The results of the compatibility test obtained a percentage score of 95% with a very decent category. The interaction capability test results are categorized as very decent with a percentage score of 85.56%. Meanwhile, in testing the performance efficiency of the D-Static application, it can run well and smoothly and there are no obstacles that make the application launch fail and force close. This test produces a time behavior of 0.026 second/frame with an average CPU utilization of 7% and average utilization of 279 Mb of storage resources. So overall the quality and performance of the D-Static application are very suitable to be used as a component introduction application at the Distributing Station for the Flexible Manufacturing System Practice course. Suggestions for the use of D-Static application products can be used by lecturers and students as learning media in the Flexible Manufacturing System Practice course. Applications can be used to facilitate practical activities in CLO (Course Learning Outcomes) about the MPS-500 Station Component and input/output. Dissemination and further development of the application are carried out to add features that do not yet exist in the application. Further development can be done by adding a dark mode feature to the application. Development can also be done by adding a list mode feature to view a list of components. Applications can also be developed on an offline basis so that users can access the full features of the application without using the internet. Similar applications can also be developed for other stations on the MPS-500 such as Processing Station, Handling Station, and Sorting Station.

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