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Evaluation of the Implementation of Augmented Reality on Vegetable Objects Using Marker-Based Tracking and SUS

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Abstract :
With the rapid development of technology in the field of information media, which initially received information from mass media, schools, electronic media and the development of Augmented Reality technology that can be applied to the field of information. Augmented Reality is the incorporation of two-dimensional virtual objects into a real environment. AR has many benefits in the field of entertainment and others. The purpose of this study is to implement information media in the form of augmented reality with a Marker-based tracking approach on leaf vegetable objects using markers in the form of paper and can display information in virtual objects, namely the content and benefits, processing of vegetables that appear as objects, producing markers that can be detected with several tests of distance, light, and marker resistance. At a distance of 10 cm – 50 cm the marker can be detected using both smartphones (Vivo and Samsung), but at a distance of 100 cm samsung smartphones are no longer able to detect due to camera differences. Marker light testing can be detected at 5 – 200 Lux light but in >1 lux marker cannot be detected and displays objects. The usability test uses the System Usability Scale (SUS) method which results in a final score of 71,583 which means that the system that has been developed is already feasible to give to users.

Keywords:
Augmented Reality;
Marker Based Tracking;
Vegetables;
SUS

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1. INTRODUCTION

Indonesia is an agricultural country known because the majority of its population makes a living as farmers. This success was supported by fertile soil which allowed agriculture to develop rapidly. Farmers in Indonesia play a key role in ensuring food security, producing a variety of commodities ranging from rice, vegetables, fruit to spices that constitute culinary and economic wealth [1]. Apart from that, local customs and wisdom also adorn every step in farming, showing harmony between culture and nature. Empowering farmers and developing agricultural technology is a focus, ensuring agriculture remains the backbone of the country's economy and sustainability [2]. Vegetables are plants that can be consumed either fresh or cooked, with various types such as leaves, stems, seeds and roots. They offer flexibility in presentation and are a source of important nutrients such as vitamins, minerals and fiber. Leaf vegetables like spinach and kale, stem vegetables like celery, seed vegetables like peas, and root vegetables like carrots all add a variety of flavors and health benefits to a diet. This variety enriches everyday dishes with nutrients that support overall health, making it a crucial element in maintaining nutritional balance.

The author made observations at one of the vegetable producers called Friends of Hydroponics and obtained vegetables that people were interested in based on sales data, namely: Romaine Lettuce, Curly Lettuce, Mint Leaf, Water Spinach, Curly Mustard Greens, Bitter Mustard Greens, Celery, Caisim, Kale, and Kailan. Results of the 2014 Individual Food Consumption Survey (SKMI), the average population's vegetable consumption was 70.0 grams/person/day and fruit consumption was 38.8 grams/person/day [3]. The population's total consumption of vegetables and fruit is 108.8 grams/person/day. When compared with the recommended adequacy according to balanced nutrition guidelines, consumption of vegetables and fruit is still low. As many as 97.1% of the population does not consume enough vegetables and fruit. When viewed from age groups, teenagers are the highest age group that consumes less vegetables and fruit, namely 98.4% [4]. The results of Riskesdas research (Basic Health Research) also say that people aged 10 years and over still do not consume enough vegetables and fruit [5].

The application of information technology in the introduction of vegetables can overcome the problem of lack of information accompanying vegetables [2]. Through the use of technology such as mobile applications or special software, detailed information about types of vegetables, their nutritional value, processing methods and recipes can be easily accessed by the public [6]. These technologies can provide visual depictions, image recognition features, or comprehensive databases, allowing users to better identify, understand, and select vegetables. Thus, information technology can be a powerful tool in increasing people's understanding and interest in vegetables, encouraging healthy eating patterns, and overcoming the lack of vegetable consumption in society. One of the modern technologies that can be developed in the information sector is Augemented Reality (AR).

In the development of Augmented Reality (AR), there are two main methods, namely: Marker-Based Tracking and Marker-Less Tracking [7]. This research chose to use the Marker-Based Tracking method which relies on patterned images recognized by the camera and matched with a template database. This process allows the integration of detected images into reality via the camera. The advantage of Marker-Based Tracking is that processing is faster than Marker-Less Tracking [8][9]. This method plays an important role in identifying and adding objects to the real environment based on identified patterns, serving as a marker identifier that allows AR implementation with more precision and efficiency.

Several previous research references have been carried out by Dewi Utari, Fera Damayanti and Divi Handoko with the aim of introducing and learning katakana letters aimed at students learning Japanese to make it more interactive and interesting. The system is designed for Android users, which works by scanning and then showing an animation in the form of a letter display [10]. Further research was carried out by Jimmi Pratama et al, regarding the application of AR in mobile-based learning media for anatomical systems in plants for school level. It is hoped that learning methods that use AR can increase students' enthusiasm for learning and curiosity [11]. Other research was conducted by Iim Abdul Rohim and Putra Jaya. By using the marked based tracking method, which produces an application that is used for teaching electronics engineering regarding the tools that will be used [12]. Next is a journal written by Irvan Dwi Saputra which raises the problem of the lack of learning media which still uses books, by utilizing existing technology such as AR in learning media about hydroponics by using markers and displaying information in the form of text and animations about hydroponic planting so that it can be easily understood [13].

In this research, the performance evaluation of the AR system was carried out using the System Usability Scale (SUS) method. This method utilizes a questionnaire with ten questions rated on a scale of 0 to 100 [14]. The higher the score obtained from the questionnaire, the better the quality of the system. The commonly used evaluation standard is 68 [15]. If the system test results are below this figure, it means that the system still does not meet the expected feasibility standards. This testing approach provides an in-depth look at the user experience regarding the ease of use and performance of the AR system being developed, becoming a crucial assessment for determining the level of readiness and superiority of the AR technology being implemented.

2. METHODS

The method used in developing Augmented Reality is Marker-based Tracking. This method uses a marker, such as paper, as the medium. The Marker-based Tracking method was used in this research because this method has faster processing than the Markerless Tracking Method.

2.1. System Overview

The Augmented Reality application as an information medium used by users after detecting the marker will display information about the vegetables, such as the contents and benefits, information about dishes that can be used to process these vegetables and also whether the vegetables are good or bad for consumption by certain diseases. This system was created using Unity 3D, Vuforia in its development to implement augmented reality technology [16]. A general overview of the system can be seen in Figure 1.

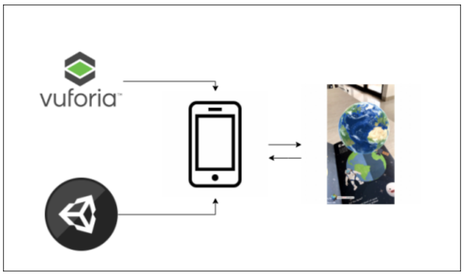

Figure 1. System Overview

In Figure 2, an example of the activity carried out by the user is scanning an existing marker, then a 3D object will appear on the smartphone camera, blending with the real world. Users also get information that is listed on this system. Figure 3 Displays information related to the vegetables that have been scanned.

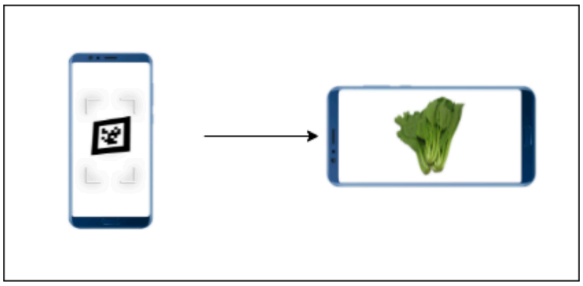

Figure 2. Scanning Augmented Reality

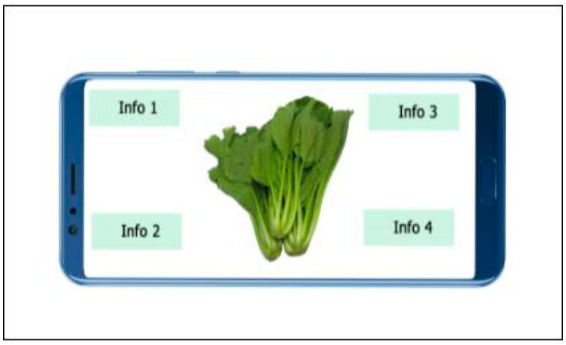

Figure 3. Information on reading results

The roles required by the system are the user who can access it and the system that displays it. The following use case diagram shows what this application can display to the user. It can be seen in Figure 4 Use Case Diagram. From the picture it is explained that:

1. Users can access the main page.
2. Users can see the About menu to see information about the system that has been developed.
3. Users can download markers on the Marker menu.
4. Users can scan markers and display virtual objects according to the markers that have been created.
5. The system can display virtual objects along with information.
6. Users can view information from virtual objects that have been scanned.

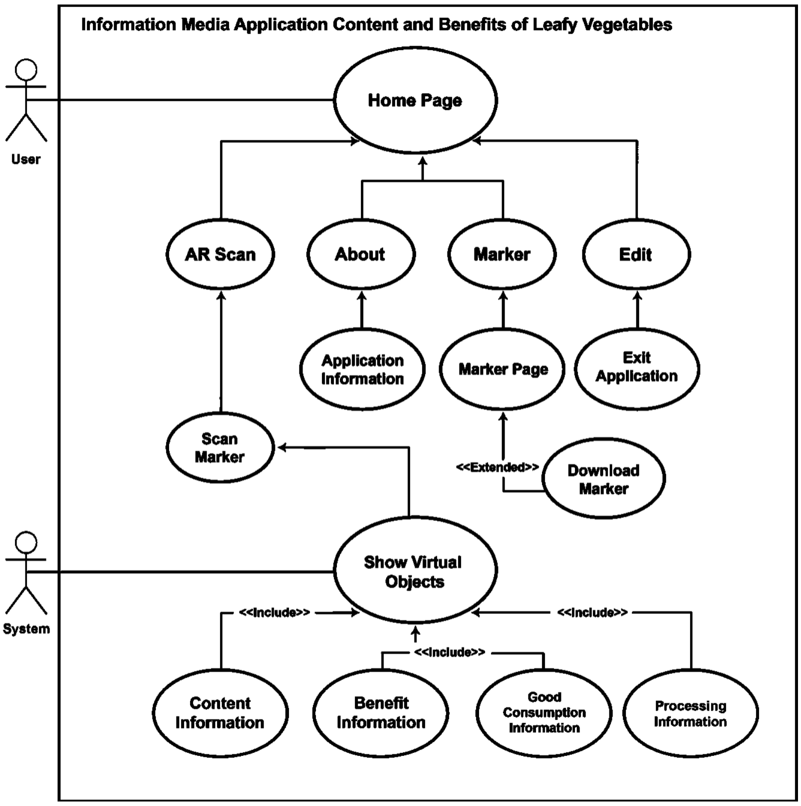

Figure 4. Use Case System Diagram

2.2. Marker Based Tracking Method

Marker-Based Tracking Augmented Reality Method Marker based tracking is a method used in applying augmented reality which functions to recognize markers and identify patterns from these markers to add a virtual object to the real environment. The marker itself is a black and white square illustration with thick black sides, a pattern that has been created according to what is desired. An example of a marker can be seen in Figure 5.

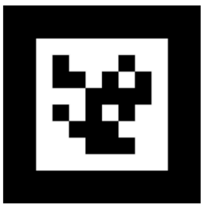

Figure 5. Marker

The Marker-Based Tracking method was chosen due to its faster processing speed compared to Markerless Tracking, particularly in environments with limited computational resources such as mobile devices [17][18]. The coordinate points on the marker have the function of determining the position of the virtual object that will be added to the real environment. The object will be perpendicular to the marker which is the center of the camera sensor. The virtual object will stand on the Z axis and perpendicular to the X and Y axes, which means that in 3D it will stand upright according to the object. The following is an image illustration of the x,y,z coordinate points which can be seen in Figure 6.

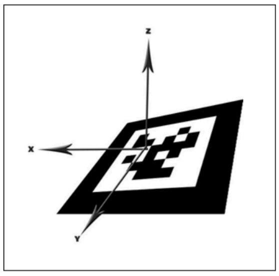

Figure 6. Coordinate X,Y,Z

In this method there is a tracking process. The tracking process is a marker detection process which has 4 processes, namely: contours extraction, corner detection, pattern normalization and template matching. This process starts at the inputImage stage, which will be processed by the processor in real time frame by frame from the camera capture. In the Contours Extraction and Corner Detection stages, we use black and white images to get the coordinates of the four sides of the marker. An overview of Countours Extraction and Corner Detection can be seen in Figure 7.

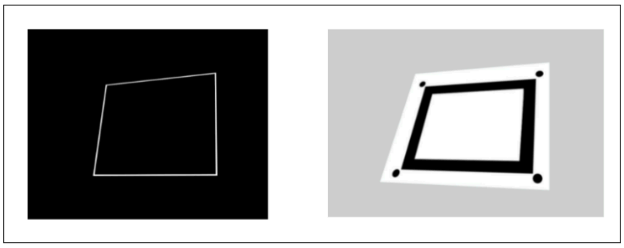

Figure 7. Countours Extraction and Corner Detection

The next stage of the marker detection stage is pattern normalization and template matching where the system processes markers that have been marked from the previous process and then produces output according to the template provided by the developer. The following is a picture of the process. It can be seen in figure 8 the Template Matching process. In Figure 8, this is the process from tracking to template matching which displays the object.

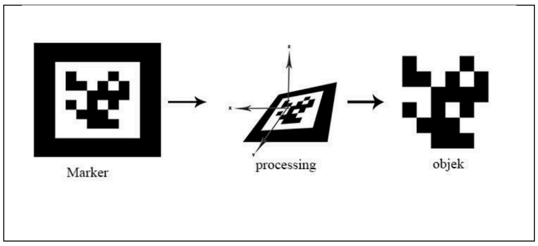

Figure 8. Template Matching and Pattern Normalization

In Figure 9, the camera process scans the marker, then the system matches the template on the marker and displays a 3D object along with information in the camera that can be integrated with the real world. The database used holds marker images created by Vuforia, and imported into Unity for the Virtual Object creation process. The next process is the pose and position estimation stage. This process emphasizes the camera pose or capturing the side of the camera sensor with the marker you want to scan. The right position is needed to match the coordinates with the captured video on the camera sensor. In Figure 9 it can be seen that it starts by detecting the presence of a camera and the user is allowed to use the camera, then the user directs the camera at an existing marker. Then the system tracks or tracks the marker and adjusts it to the appropriate template and displays the 3D object in the camera along with the existing information.

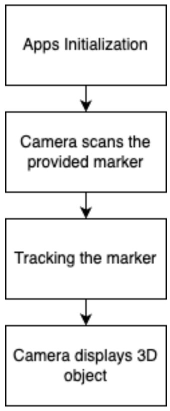

Figure 9. Flowchart Marker Based Tracking

Figure 10 shows an image in the form of a splashscreen that will appear when the user first opens this system.

Figure 10. Main Menu Display

Figure 11 shows the initial display or Home display where the user can select the menus in this system. In the SCAN menu the user asks for permission to use the camera on the smartphone used by the user, then the user scans the marker that has been provided. After the tracking process is successful, an object will appear that is integrated with the real world and will display the information contained in the object. The ABOUT menu displays information about the developer of the application such as name, ID, institution where the author conducted research, and displays other information about this system. In the EXIT menu, users use it to exit the system if there is nothing else they want to do in this system.

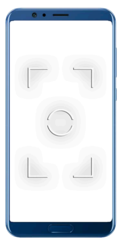
Figure 11. Scan Menu Display

3. RESULT AND DISSCUSSION

By using Augmented Reality you can present more interactive and interesting information. The information displayed in this application is:

1. Ingredients The contents of the vegetables shown
2. Benefits of vegetables as objects and also their benefits for the human body
3. Good for Consumption Displays information if the vegetable is good for consumption for a particular disease
4. Information processing in the form of processing methods for these vegetables

3.1.Marker

The following figure 12 is the marker used in this research.

Figure 12. Example of Marker

After scanning the marker, the application will display a virtual object according to the template. Virtual objects and their information will appear on the Z axis or stand upright above the marker. The following illustration of the Z axis can be seen in Figure 13.

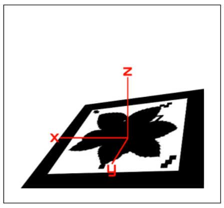

Figure 13. X, Y, Z coordinate points

Marker detection process, markers that have been made with pictures of vegetables and then added black boxes and numbers to help detect markers on the camera. That is also what makes the marker unique and easy to read by the camera. This also helps in increasing the rating assessed by Vuforia Engine as making good markers. You can see in the image above, the points detected by the camera. Then it is matched with the marker that has been created in the database. If it matches, a virtual object will appear that matches the marker. The function of the black box around the marker functions as a marker that inside it is a marker that has been created for an Augmented Reality system that has been created. If you don't use a box around it and only use the image inside it, the camera can still detect markers that match the template, however, this is used if there are many image objects that the camera sees directly at the same time. The black box around the marker functions to carry out the first scanning as starting points. There is a time difference in displaying virtual objects using a marker box and not using a marker box if one camera has many objects detected by the camera. The design of the reading information along with the markers used can be seen in Figure 14.

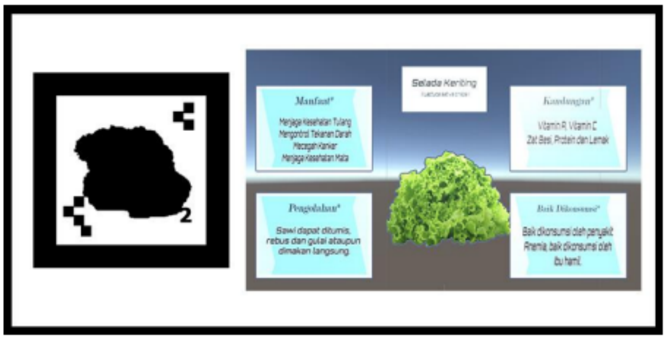

Figure 14. Curly Lettuce Vegetables

3.2. App View

Main Menu Page Display the main menu of this application. In figure 15 is a display of the Main Menu of the application being developed

Figure 15. Main Menu Display

AR Scan Menu Display Displays the camera ready to scan markers. Figure 16 is an example of the AR scan menu and successfully scanning the marker

Figure 16. Smartphone Camera View

3.3. Testing

The testing method used is Black-Box Testing. Black Box Testing is testing that focuses on the output in selected responses and execution conditions by ignoring the internal mechanisms of the system such as source code. In this application there are 2 things tested using this method, namely:

3.3.1. Functional Testing

Based on the tests that have been carried out, the results obtained can be seen in table 1 below.

Table 1. Table of Functional Testing Results

No	Menu	Results
1	AR Scan	Success
2	About	Success
3	Marker	Success
4	Exit	Success

In the tests that were carried out, it was found that the 4 menus that had been created were successful according to the desired function and appearance, namely the AR Scan menu which successfully displayed the smartphone camera ready to scan the marker. The About menu successfully displays information about the application. The Marker menu which successfully displays how to use markers and download existing markers, and the Exit menu which has successfully carried out its function, namely to exit the application.

3.3.2. Non-Functional Testing

At this stage, several obstacles that the system will face are tested to see whether the system can overcome and complete the tasks given by the user. Markers are printed using paper measuring 8.2 cm X 8.2 cm.

Some aspects tested are:

a. **Lighting**

The lighting tests were conducted using a smartphone camera and a lux meter application to measure light intensity. The environment was controlled by turning off and on artificial lighting sources, with light levels ranging from over 200 Lux down to below 1 Lux. The smartphone camera was mounted on a fixed stand to maintain consistent distance and angle during each test scenario.

One very important factor in marker detection is lighting. Light plays an important role so that markers are easily seen and captured by smartphone cameras. If the marker's environment is dark or lacks light, it makes it difficult for the marker to be detected by the camera and virtual objects will be difficult to appear. In this test, software is needed to measure the intensity of light, namely Lux Meter. This test was carried out in the room, here are the results of the lighting test:

1. Light >200 Lux

   In light above 200 Lux, the marker can still be detected well, with the marker being made in black and white, the marker is not too disturbed by high light.

2. Light 5 – 10 Lux

   Markers can be detected well.

3. Light >1 Lux
   In the last light test the marker could no longer be detected with a light intensity of 1 Lux or less below the light test results > 1 Lux.

Light testing can be seen in figure 17.

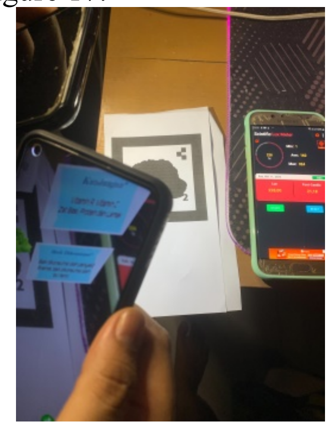

Figure 17. Lighting Testing

b. Distance

The distance tests were performed with a ruler and fixed tripod setup to ensure accurate measurement between the smartphone camera and the printed marker. The virtual object clarity and system responsiveness were recorded at 5 cm, 10 cm, 30 cm, and up to 100 cm. The test also confirmed that camera quality differences between devices affected recognition at longer distances.

Apart from light, distance is also an important factor in whether a marker is detected or not. When the marker and camera are too far away, it makes the virtual object small and difficult to see the object and its information, conversely, if the distance between the marker and camera is too far, it makes the virtual object too difficult to see and arrange the object above the marker. The following are the results of the distance testing that has been carried out:

1. Distance 5 cm
   The marker can be detected but the position of the virtual object in relation to the camera is too large and difficult to see in full.
2. Distance 10 cm
   Markers can be detected well, objects and all information can be seen clearly and thoroughly.
3. Distance 30 cm
   The marker can be detected well, with the display of the object appearing also having a small comparative size due to the distance between the marker and the camera being not optimal. This also causes the information contained in virtual objects to become difficult for users who use this application to read.

Testing the reading distance from the marker can be seen in Figure 18.

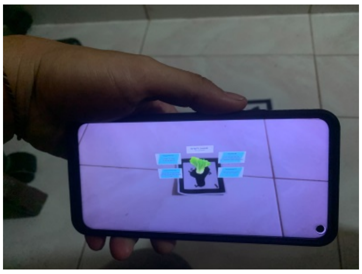

Figure 18. Distance Testing

c. Marker Resilience

In testing the resistance of the marker, it plays an important role in whether or not the medium used as the marker is clear. If the marker is not clear enough, it will be difficult for smartphone cameras to detect it. The following is a marker durability test.

1. Marker Visible 80%

   The marker can still be detected by the smartphone camera well, from a marker size of 80%, around 1.6 cm of the area is covered. So it can be said that the quality and uniqueness of the markers are still quite good.
2. Marker visible 50%

   The marker can no longer be detected by the smartphone camera so it cannot display virtual objects on the camera. Because markers have their own characteristics compared to other markers, if the shape of the marker is only 50% of the actual one, the system cannot match the virtual object that matches the marker.
3. Marker Visible 60%

   In the scanning marker test using a marker that is 60% visible, the marker can be detected, but the virtual object that appears is unstable and moves due to the marker not being fully visible, so that it is difficult for the virtual object to determine the vertical angle to display the virtual object from the marker.
4. Marker is damaged

   When the marker is crushed and immediately scanned with the marker paper damaged, the camera cannot detect it properly. However, after the marker paper is tidied up so that it looks like a square again, the system can detect it and immediately display the virtual object.
5. Marker is cut.

   When the marker is torn into two parts with a distance between the parts of 1 cm between the markers, the system can still display the virtual object in the camera properly but the condition of the object is irregular, if the distance between the torn parts of the marker becomes wider it will make it difficult for the system to place the object in the part. left or right marker. Then the virtual object displayed will move randomly in the camera.
6. Testing Without Marker Box

Tests have been carried out without a marker box at a distance of 15 - 20 cm, only using marker images. And produces markers that can be detected and display virtual objects. However, there are differences in the speed of detecting markers and displaying virtual objects. If when the camera scans the marker with various objects the marker box indicates that it is a marker that has been created and can display virtual objects. The difference between the trials carried out is that there is a difference of 0.4 – 0.6 seconds in marker detection.

The results of the marker durability test, the marker can be successfully detected after a series of tests that may occur such as the marker being damaged, the marker being cut. For truncated markers, if the distance between the truncated markers is still close, such as 1 cm, the marker can still be detected but changes occur in the appearance of the application, such as virtual objects that are unstable and moving. Markers that are 80% covered can still be detected with time, but for markers that are 50% covered they cannot be detected by the camera. The 60% marker can still be detected but the virtual object that appears is moving unstable. Durability testing can be seen in Figure 19.

Figure 19. Marker durability testing

d. Usability Testing

The System Usability Scale (SUS) was selected as the evaluation method because it provides a quick, reliable tool for measuring usability. SUS is widely used in usability studies due to its ease of implementation and interpretation across different systems [19]. Compared to methods such as the Usefulness, Satisfaction, and Ease of Use Questionnaire (USE), SUS offers more concise results while still covering key usability metrics. SUS is reliable even with small sample sizes and is suitable for early-stage prototype evaluation [20].

In this research, a survey was conducted to carry out usability testing using the System Usability Scale and it was found that 30 respondents had answered the questions given on the form. The following is how to calculate using the System Usability Scale method, namely [21]:

1. For each question in odd order, reduce the value by one. For example, question 1 has a score of 4. Then subtract 4 from 1 so that the score for question 1 is 3.

2. For each question in even order subtract the value from five. For example, question 2 has a score of 1. Then subtract 5 from 1 so that the score for question 2 is 4.
3. Add the values of the even and odd numbered statements. Then the sum result is multiplied by 2.5.

The results from the System Usability Scale calculation for this application were 71.583 which can be categorized as good. If the final result of the SUS calculation is less than 68 then it can be categorized as less feasible, and the system has usability problems so system improvements need to be made.

4. CONCLUSIONS

Based on the results of the implementation and testing that has been carried out, conclusions can be drawn, namely:

1. The application using Augmented Reality has successfully passed several tests by displaying virtual objects according to the markers that have been created. For functional testing of the 4 menus that have been created, 4 menus have been successful as desired. The results of non-functional testing are external factors that influence the scanning of markers, such as test lighting for > 1 lux markers cannot be detected, for sizes 5 lux - > 200 lux markers can be detected well. Distance testing found the results from distance measurements, 5 cm – 50 cm, both hardware can still detect the marker, but the virtual objects that appear vary according to the distance. The farther the marker is, the smaller the virtual object. The optimal distance that is best for detecting markers is 15 cm – 25 cm for virtual objects whose information appears easy to see and read. Marker resistance testing resulted in 80% visible markers, the smartphone camera could detect the marker, while 50% visible markers resulted in the marker not being detected and the virtual object not being able to appear on the camera. When the marker is torn in half with a distance of 1cm between the tears, the marker can still be detected, but the virtual object that appears is difficult to control and continues to move.
2. Testing application performance using the System Usability Scale resulted in a final score calculation of 71,583, which means it is good and suitable for use by users to obtain the information contained therein.

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