Design of Microcontroller-based Secondary Surveillance Radar as a Learning Media

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Abstract. Secondary Surveillance Radar (SSR) is a flight surveillance facility whose function is to monitor and supervise aircraft movement activities in the air. This guide aims to: 1) design a radar that collects aircraft information, 2) create a tool that can be useful for cadets learning at the Makassar Aviation Polytechnic campus. The research method used is the waterfall method. The waterfall method used in this study is a method that involves the stages of needs analysis, design, development, testing, and implementation of the Secondary Surveillance Radar which aims as a learning medium whose working principles are following the actual equipment. The results of this study produced 2 tools, namely an aircraft that provides aircraft identification using ESP8266 and an ultrasonic sensor to generate aircraft altitude information, while a radar tool generates distance information between the aircraft and the radar using an ultrasonic sensor with a maximum distance of 100cm driven by a stepper motor to obtain angle information. then displayed in the form of an image using a processing application. So the authors made a Microcontroller-based Secondary Surveillance Radar (SSR) design where this tool can get information according to the actual equipment in the field.

Keywords: Radar, Ultrasonic Sensor, Motor Stepper, Arduino Nano, SSR

1 Introduction

One of the areas of concern for technological developments in aviation is the field of surveillance. Surveillance is an observation facility that assists flight operations in observing and guiding flight traffic to achieve flight safety. One example of using technology in surveillance or flight observation equipment is Radio Detection and Ranging (Radar).

Several types of radar are commonly used at airports, namely Primary Surveillance Radar (PSR), Secondary Surveillance Radar (SSR), and Monopulse Secondary Surveillance Radar (MSSR). PSR, SSR, and MSSR have different ways of working. The PSR radar only receives information from reflected radio waves from the aircraft (echo), while the SSR and MSSR receive data from the transponder on the plane.

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Surveillance equipment, one of which is RADAR equipment, needs daily, weekly, monthly, and annual maintenance so that the performance of the RADAR equipment remains stable. To carry out this maintenance, highly competent human resources are required. To produce these human resources, the Makassar Aviation Polytechnic makes these human resources through the Air Navigation Technology study program.

Current conditions at the Makassar Aviation Polytechnic still need learning media, surveillance equipment, or practicum tools to support learning. In the learning process, cadets study the theories of several tools, for example, communication, navigation, observation, and automation. However, with just theory alone, it is still difficult for cadets to understand the working principle of this tool. With that, the researcher created a learning medium to make understanding the operating principles of aviation surveillance equipment facilities easier. One of these facilities is radar.

To make it easier for cadets to study on campus, we need a learning media that can help cadets, especially learning about radar equipment, and from there, cadets know what information is obtained by radar from aircraft.

The author refers to several relevant previous studies in the research, including the following.

State-of-the-art three-dimensional (3-D) imaging sonar sensors possess the ability to accurately see and comprehend the entire surrounding environment. However, when the distance rises, these systems begin to have difficulties in detecting objects due to inadequate sound transmission over the air, resulting in a signal-to-noise ratio that becomes too low. When considering other sensing methods, such as radar, this issue is addressed by employing systems that incorporate many elements in the transmission and/or reception phase, hence achieving an extended effective detection range. At this greater distance, the resolution of the acquired image will likely diminish. Both radar and underwater sonar systems utilize synthetic aperture techniques to enhance the spatial imaging resolution. This letter presents a novel approach that combines two methodologies to develop an in-air sensor called simultaneous transmit synthetic aperture beamforming (STSTAB) sensor. The sensor is based on the eRTIS 3-D sonar sensor and aims to enhance the system's range and angular resolution while maintaining a high measurement rate. Various aspects of the emitter array will be examined, including the most advantageous positioning of its elements, as well as the simultaneous emission of coded signals. The outcome will be a high-speed imaging sonar sensor with a focused point-spread function and enhanced range [1].

The experimental findings unequivocally establish the system's exceptional efficiency in remotely controlling diverse appliances, boasting a remarkably swift response time of under one second. The study finishes by emphasizing the possible uses of the system, such as its utilization in smart homes, and its ability to enhance energy efficiency and security. In summary, this research paper emphasizes the practicality and advantages of employing wireless home automation systems with the Blink IOT application and various components including the ESP8266, ULN2003, relay switches, microcontroller, and AC load. This technology proves to be extremely valuable for homeowners who desire enhanced convenience and automation in their everyday routines [2].

System Development Life Cycle (SDLC) is a general methodology used to develop information systems. SDLC consists of several phases, starting from the planning, analysis, design, implementation, and system maintenance phases. The waterfall method is an SDLC model often used to develop information systems or software[3].

The system utilizes a PIC microcontroller programmed with the Flowcode language to process instructions. Position feedback is received through the utilization of a photo-sensor, while the H-Bridge driver is employed to regulate the operation of two DC motors. Based on the experimental findings, the suggested system demonstrates substantial enhancements in efficiency when compared to stationary solar tracking systems [4].

A room temperature and humidity monitoring system is essential for specific activities. This can be achieved using a computer-based data acquisition system. Typically, apps operating on a personal computer serve the purpose of presenting and storing measurement outcomes. Nevertheless, these programs typically have limited compatibility with specific operating systems and are created using proprietary licensed software. The objective of this research is to develop a cross-platform application for monitoring room temperature and humidity on personal computers using open-source software. The application's graphical interface was created using the Processing programming tool. The software development method known as PSP (Personal Software Process) is a straightforward process. The application interface was created using wireframes generated by the Pencil Project program. Through experimentation conducted in both Windows (Windows 7) and Linux (Ubuntu 14.04) operating systems, the application successfully received temperature and humidity data from data acquisition devices using serial communication (USART). It then displayed this data and recorded it into a text file in CSV format (Comma-Separated Values). The application is expected to undergo additional development to provide functionality for managing data acquisition devices from a personal computer [5].

This study presents a novel control system, utilizing Arduino technology, to address the issue of children being left unattended in cars. This system introduces novel functions compared to those described in existing literature or already available on the market, with the aim of enhancing safety and reliability. The suggested system incorporates a mobile application that enables the reception of alarm or status messages, as well as photographs immediately captured from the car cockpit. Furthermore, the application enables remote control of several automotive operations, like activating the horn, lowering the windows, and locking/unlocking the doors. The extensive array of utilized sensors enables the resolution of some detectability limitations encountered by comparable detection systems [6].

The experimental findings illustrate that the system exhibits a high level of efficiency and possesses the capability to remotely manage a wide range of appliances, with a response time of less than one second. The study finishes by emphasizing the possible uses of the system, such as its utilization in smart homes, and its ability to enhance energy efficiency and security. In summary, this research paper emphasizes the practicality and potential advantages of employing wireless home automation systems with the Blink IOT application and multiple components including the ESP8266, ULN2003, relay switches, microcontroller, and AC load. This makes it an extremely valuable resource for homeowners desiring enhanced convenience and automation in their everyday routines [7].

The result of this design was that cadets could learn the display of ADS-B on the PC/laptop monitor screen which was available in the classroom or laboratory even though it's not as real as the original ADS-B, this design could display the surveillance system that was not very different from the real or original one [8].

2 Method

2.1 Research Design

Based on the research methods that have been carried out, the block diagram of the overall research design of the tool is shown in the image below.

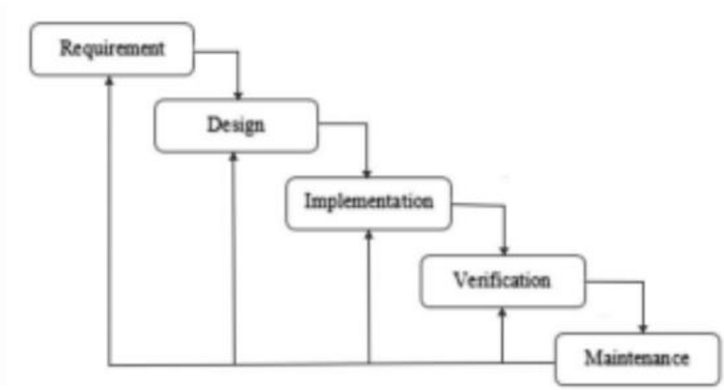

Fig. 1. Research Flowchart

2.2 Research Variable

The first step in making this tool is collecting the materials that will later be completed in one place.

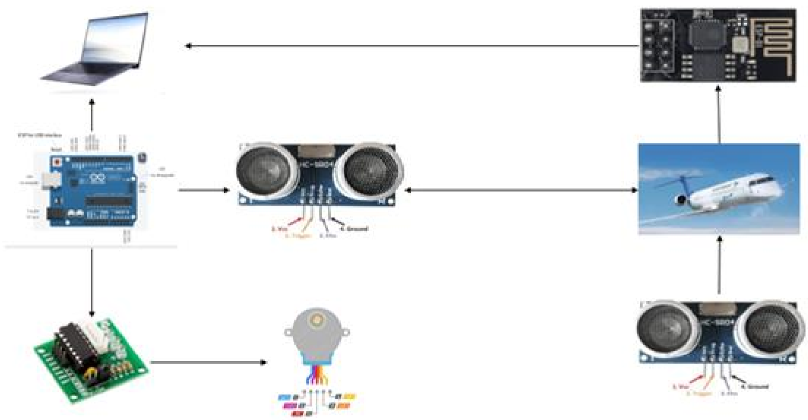

Fig. 2. Design of the Mock-up

How this tool works is as follows:

1. When the Arduino is turned on, the Arduino turns on the ULN2003 Driver to regulate the rotation of the Stepper motor, which has been given voltage and rotates the ultrasonic sensor 360 degrees to detect objects and calculate

their distance

2. When the ESP8266 gets voltage from the battery, the ESP8266 will continue to send data, namely aircraft code and altitude obtained from the ultrasonic sensor.

3. When the ultrasonic sensor detects an aircraft in the 1-100 cm range, the data will be sent to the Arduino along with the angle, and processing will visualize it and the data on the aircraft.

2.3 Testing

The test steps that will be carried out are as follows: At this stage, the author tests the tool's performance, whether it is working well or not according to its function. The stages in testing this system were declared successful when both devices, namely the Radar and the aircraft, could send, receive, and display data. In the radar circuit, testing is carried out to ensure that the installed components are in average condition. The ultrasonic sensor gets distance information, and the stepper motor sends angle data, which is then sent to Arduino, after which Arduino will send it to processing to be displayed on the monitor. he Aircraft Transmitter circuit consists of a battery, ESP82, and Ultrasonic Sensor. In the aircraft transmitter circuit, testing is carried out to ensure that the installed components are in average condition. The ultrasonic sensor obtains height information from the ground to the aircraft, and then the data is transmitted to the ESP8266-01 to be sent to the Radar.

3 Results and Discussion

3.1 Radar Display

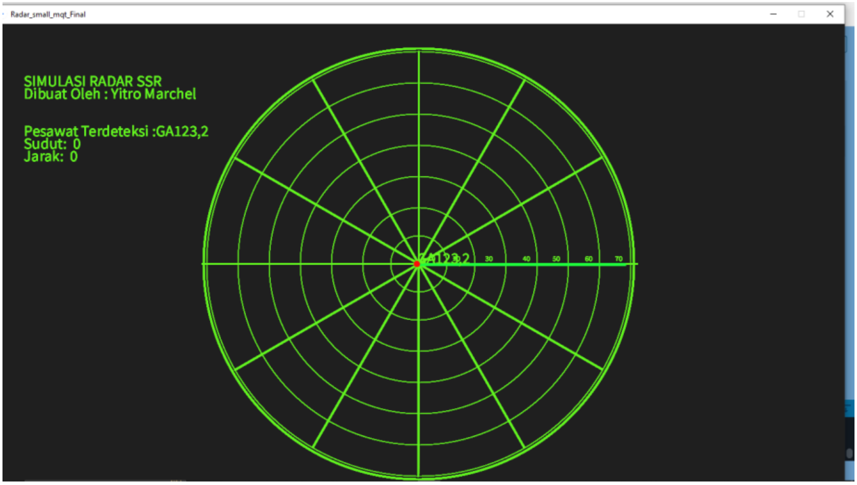

Fig. 3. Radar display

The initial image display displays a circle, which will later show the object in real-time. In this display, seven circles are created, each of which is a multiple of 10 cm from the center point. Meanwhile, the display in the top left corner also displays data in real-time but in text form.

3.2 How to use

Fig. 4. Step 1: Connect the cable to the laptop and the power supply from the radar

Connect the radar device, namely connecting the Arduino Nano to a laptop using a USB Type C cable and connecting the USB cable to the power supply from the ULN2003 Driver to drive the stepper motor.

Fig. 4 Step 2: Connect the aircraft tool to the power supply

When all the devices are connected to the laptop, open the device manager to see how many COMs the Arduino Nano uses. Testing at a distance of 60 cm

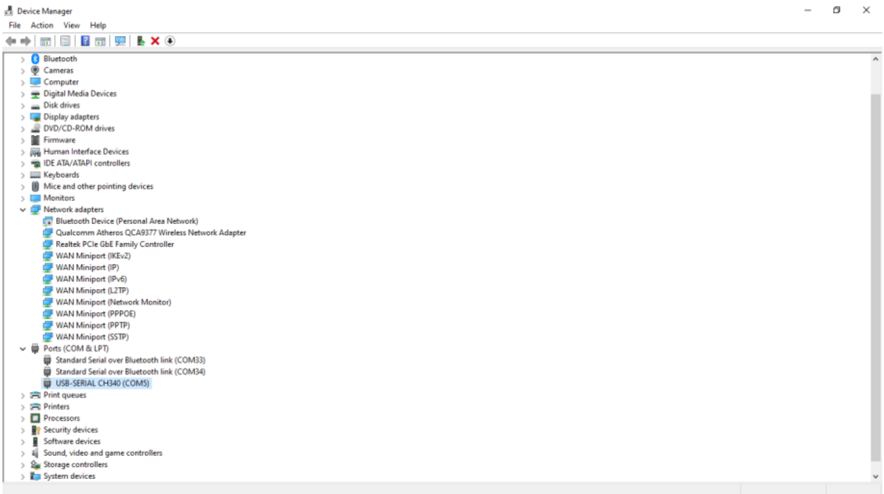

Fig. 5 Step 3: Checking Available Port

1. Open the Processing Application

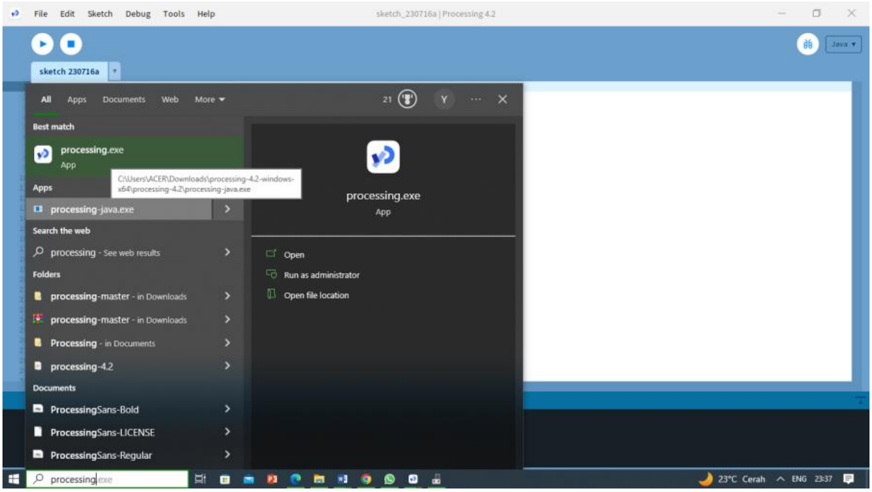

Fig. 6 Step 4:Processing Application

2. Open the coding that was created previously

3.

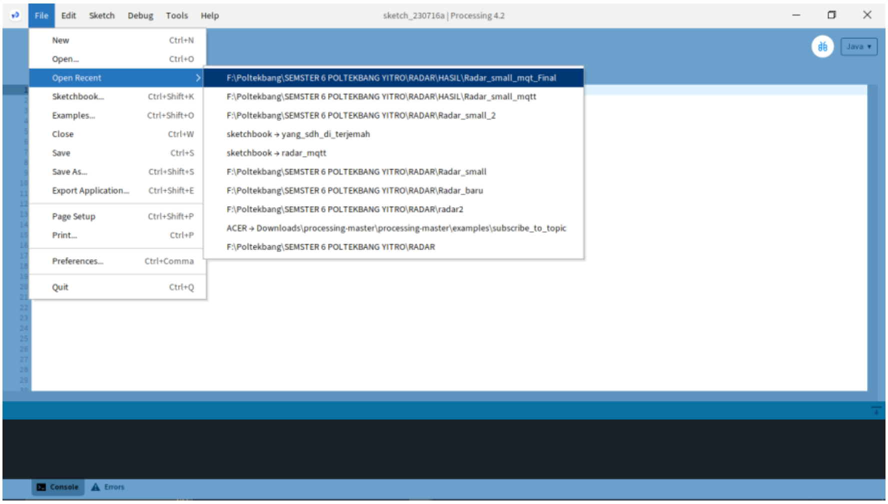

Fig. 7 Step 4: Opening Coding Files

3. Customize COM in the Device manager

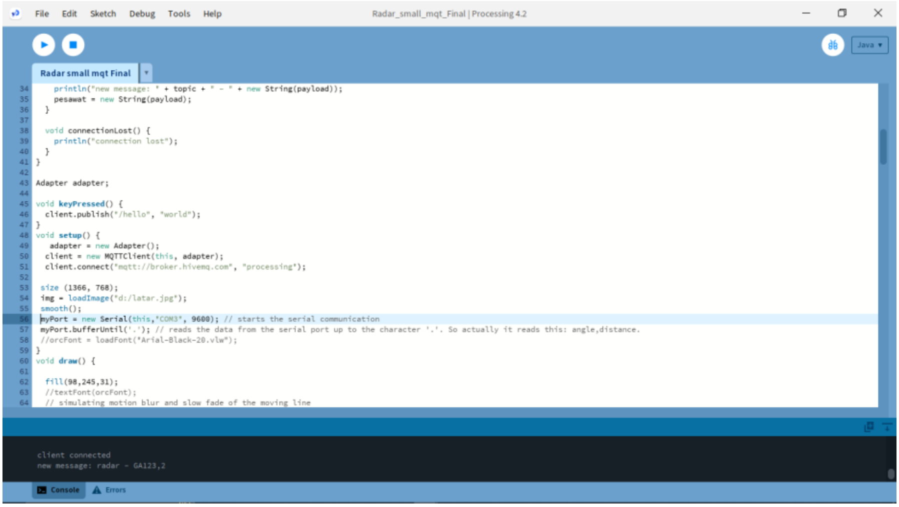

Fig. 8 Step 4: Adjust the COM

4. When you have adjusted the COM used, press the Play button in the top left corner to display the image.

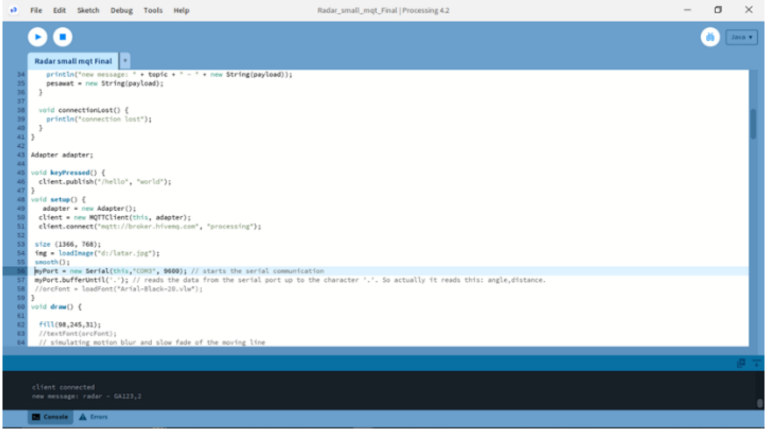

Fig. 9. Play to open the radar display image

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5. After everything is connected, the image will display data obtained from the radar and aircraft.

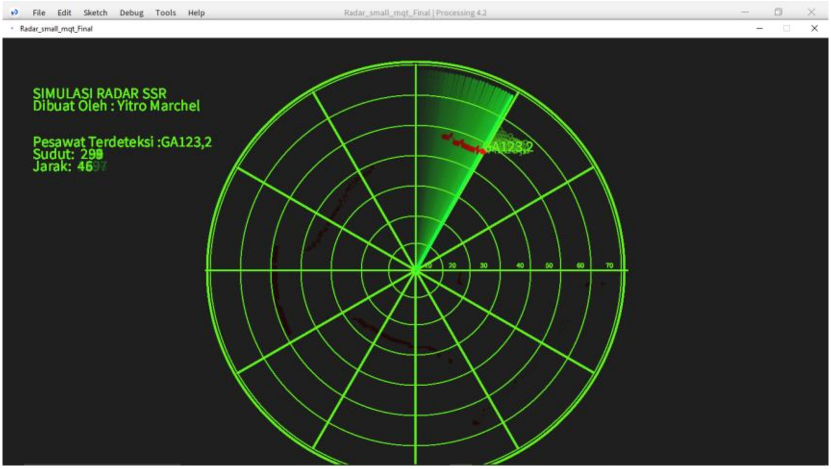
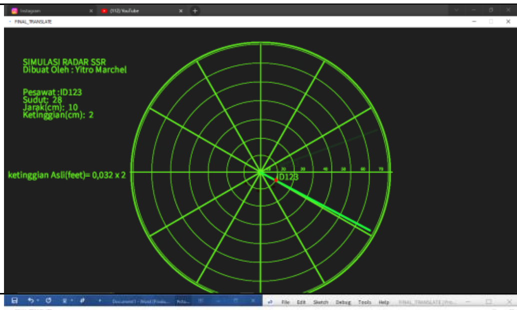
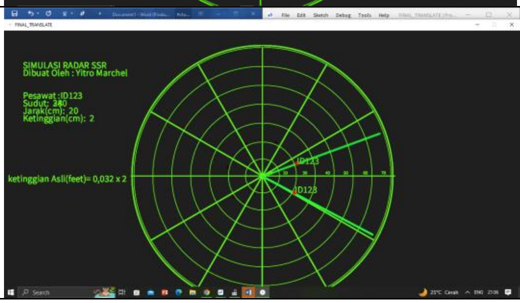
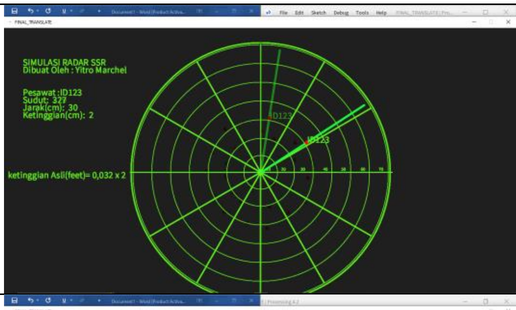
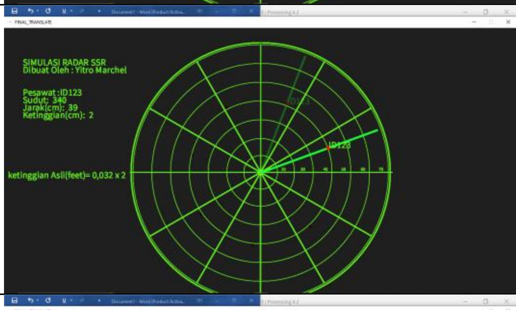
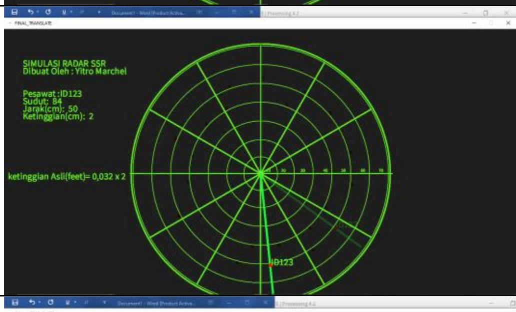
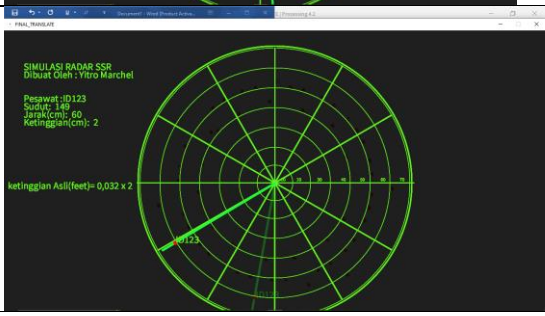


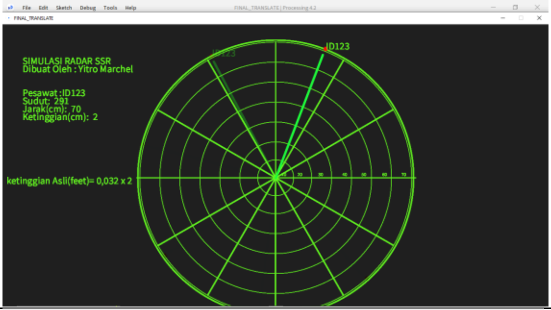
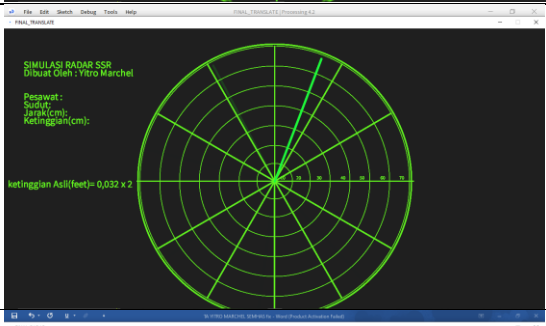
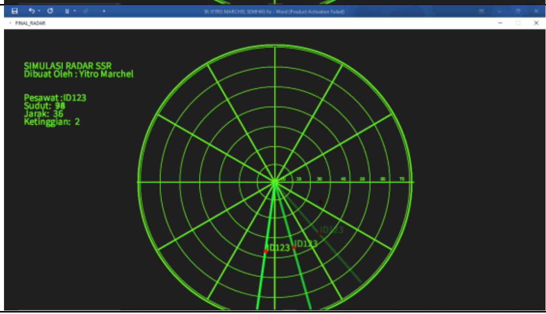
Fig. 10 Image Display when Getting Data

b. Tool Testing
Whole system testing

Table 4. 1 Tool Testing

Testing at a distance of 10 cm	
Testing at a distance of 20 cm	

Testing at a distance of 30 cm	
Testing at a distance of 40 cm	
Testing at a distance of 50 cm	
Testing at a distance of 60 cm	

Testing at a distance of 70 cm	
Testing at a distance more than 70 cm	
Testing with a distance of 1-70 with non-aircraft objects	

The overall test results show that the radar can detect aircraft at a distance of 1-70 cm and display the desired data, namely angle, distance, aircraft identity, and aircraft altitude. Meanwhile, when the plane is more than 70cm, it will not display data. In the results of this test, the radar can also detect objects other than aircraft, so when there are objects other than aircraft at a distance of 1-70 cm, the radar will display data from the aircraft. To determine the original distance between the plane and sea level, multiply it by 0.032 feet because 1cm=0.032 feet.

Conclusion

Based on the test results above, the following conclusions can be drawn, the author can conclude that the SSR radar design is divided into two tools, namely the SSR Radar and the aircraft as an object. The SSR radar uses an ultrasonic sensor to detect the distance from the radar to the aircraft, a stepper motor to rotate 360 degrees, and an Arduino Nano as a controller for the rotation of the stepper motor and a reader of the signal received by the ultrasonic sensor. Meanwhile, aircraft as objects use an ultrasonic sensor to detect the distance from the plane to the ground, and the NodeMCU ESP8266 as a data receiver from the ultrasonic sensor is then sent to radar. The detected aircraft can be seen using the Processing application according to the distance, angle, identity, and altitude. How it works: This design means that the Arduino Nano provides input for the stepper motor to rotate 360 degrees to rotate the ultrasonic sensor. During rotation, the ultrasonic sensor sends an ultrasonic wave signal; when the signal hits the aircraft, the signal will be reflected and received by the ultrasonic sensor and sent to Arduino, which is then displayed in the processing application. The Processing will also display data from the aircraft. Meanwhile, the way the aircraft transmitter works is that the ESP8266 commands the ultrasonic sensor to send a signal downwards to measure the altitude. After the altitude is obtained, the ESP8266 sends the results to Processing to be displayed. The test results are that the radar can demonstrate the required data, namely the aircraft's angle, identification, distance, and altitude, with a maximum distance of 70 cm between the plane and the radar.

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