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Design of automatic aircraft parking system module visually guidance display using ESP32 Microcontroller as practical media

Nurwijayanti Kusumaningrum*, Yogi Setiawan
Department of Electrical Engineering, Universitas Dirgantara Marsekal Suryadarma

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ABSTRACT

A visual guidance display is a module that was created to assist the pilot task when parking his plane or helping to control aircraft parking at the airport. Up to now, the pilot task is still assisted by a parking attendant (Marshaller) whose aim is to guide the movement of the aircraft to the parking lot. So, a practicum module was made as a medium of learning and knowledge along with the use of alternative technology. This module uses a Visual Guidance Display (automatic aircraft parking aid). This module design uses 3 32x8 pixel dot matrix display boards with dimensions of 13x3.5 cm which are combined into one to form an appropriate combination to produce a parking direction display. The display used is a super right led dot matrix. The controller is an ESP32 microcontroller and a series of shift registers to display the right, left, straight, and stop motion views as well as the distance display of the aircraft to the parking stop point on the apron.

Corresponding Author:

Nurwijayanti Kusumaningrum,
Electrical Engineering,
Universitas Dirgantara Marsekal Suryadarma,
Protokol Halim Perdanakusuma, Bandara Halim PK, Jakarta Timur
Email: nurwijayanti_kn@yahoo.com

1. INTRODUCTION

The Airports that are busier and equipped with better facilities are at risk of increasing the number of accidents. Therefore, major airports in the world are competing to use an integrated system that can be controlled more quickly and easily. The trend is smart airports, where all aspects of airport operations are connected in one good system [1]. Prevention of incidents or accidents can be done. Even if an accident occurs, the solution is handled more quickly.

So, the challenge is to increase airport capacity with increased safety as well. One of the things that can be done in the "apron" area is to apply "marshaller automatic", where the marshaller not only gives a signal for the aircraft to park but is also able to continuously monitor the condition of the aircraft, such as providing real-time reports on the condition of the aircraft in motion Parking [2].

In this case, special attention is paid to the movement of the aircraft taxiing to the parking lot. This method has a very important role in providing safe and comfortable services for every company engaged in air transportation, referring to the Aviation Law No.1 of 2009. As technology develops, it is likely to be implemented at every airport in the future. Every aircraft that will park at the parking stand no longer uses a parking interpreter (marshaller) but uses increasingly sophisticated equipment. Then a learning module was made in the laboratory so that students understand the microcontroller-based aircraft parking system [3].

Visual Guidance Display is a piece of equipment that guides aircraft on the ground visually to the parking lot on the Apron automatically [4]. The guidance system on this module is designed to provide fast, smooth, and precise docking guidance to the gate terminal. The Frequency Marker controls the aircraft type to ensure that it matches the information provided to the dock. It displays clear and visible information to the pilot on a high-intensity LED display for correct docking directions.

Visual Guidance Display can increase speed and accuracy compared to using a parking attendant (marshaller). Parking without using a marshaller will be more effective because the use of parking staff (marshaller) will be constrained during bad weather and allow the same staff to handle other tasks on the apron that result in delays in aircraft departure (delay), as well as minimize the movement of the number of airport officers working around the apron for security reasons [5].

2. RESEARCH METHOD

2.1. The Airport

According to Annex 14, the sixth edition of ICAO (International Civil Aviation Organization), an airport is an area on land or water (including buildings, installations, and equipment) that is designated either in whole or in part for the arrival, departure, and movement of aircraft. According to Law No. 1 of 2009 Chapter I, Article 1 Paragraph 33 states that an airport is an area located on land and waters with certain boundaries which are used as a place for aircraft to land and take off, board and drop passengers, loading and unloading goods, and places for intra and intermodal transportation, which are equipped with aviation safety and security facilities [6], as well as basic facilities and other supporting facilities.

2.1.1 Airport's Function

According to the Law of the Republic of Indonesia No. 1 of 2009 concerning Aviation, the function of airports is to support the smooth, secure, and orderly flow of air, cargo, and/or postal traffic, flight safety, places of intra and/or mode transfer and to encourage the economy both regionally and nationally. The Airports based on their function are divided into 3, namely:

1. An airport is a node in the center of the air transportation network in accordance with its hierarchy of functions, namely the airport as a distribution center and not a deployment center.
2. The airport is a gateway for national and international economic activities.
3. The airport is a place of activity for the transfer of transportation modes.

2.2. Apron

An apron is an airside facility from an airport that bridges the runway with the terminal building. The apron is provided as a place for aircraft when carrying out activities for loading and unloading passengers, loading postal and cargo from aircraft, refueling, parking, and aircraft maintenance [7]. The apron consists of aircraft parking areas (Ramps) and aircraft circulation and taxiing areas to get to the ramp. Planes park in an area called the gate. There are several aircraft service activities on the apron, namely:

1. Refueling
   Aircraft refueling is determined based on needs, according to the flight route.
2. Baggage handling
   Baggage is transferred to and from the aircraft during aircraft service upon arrival and before departure.
3. Catering
   Equip the airplane kitchen with food and drinks before the flight departure.
4. Aircraft Maintenance
   Aircraft Mechanics has the task which working on aircraft maintenance.

2.3. *Parking Stand*

A parking stand is an area where the aircraft is parked during ground service, with a minimum distance of 7.5 meters from the side of the aircraft except for the wing tip safety distance which can be reduced to a minimum distance of 3.5 meters. This area must be safe from any vehicles or equipment while the aircraft is in motion.

Meanwhile, based on the aircraft parking position, there are 4 (four) types of parking, namely:

1. Nose-In

It is an aircraft parking system with the nose of the aircraft perpendicular as close as possible to the terminal building.

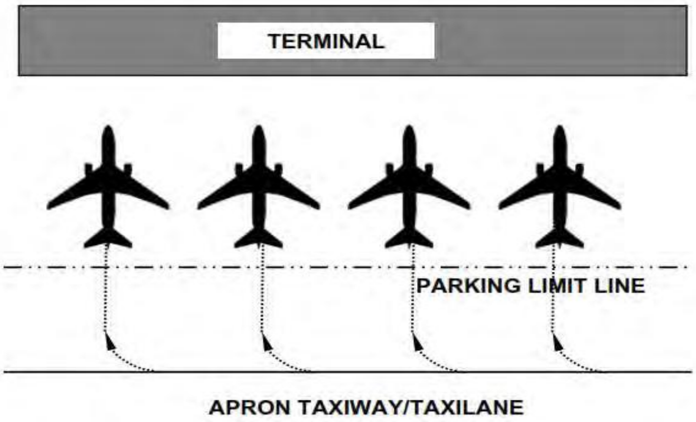

Figure 1. Nose-in parking

From the figure 1 above, obtain the advantages and disadvantages of the parking system, as follows:

Table 1. The advantages and disadvantages of nose-in parking

Advantage	**Disadvantage**
Does not require a large aircraft parking space	Requires a push or pull tool when the airplane enters and exits the parking stand
Minimize the noise from aircraft engines	The operation of removing the aircraft from the apron takes time and staff expertise
Picking up and dropping off passengers just got easier	

2. *Angle Nose-In*

It is called an aircraft parking system in which the nose of the aircraft faces the terminal building, forming a 45º angle to the terminal building.

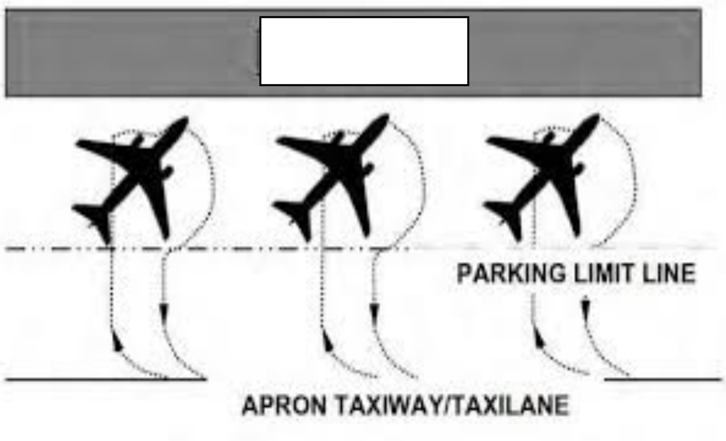

Figure 2. Angle nose-in parking

From the figure 2 above, obtain the advantages and disadvantages of the parking system, as follows:

Table 2. the advantages and disadvantages of Angle Nose-In Parking

Advantage	Disadvantage
Not require assistive devices needed when exiting the parking lot	Requires a wider apron area than Nose-In There is noise from the aircraft engine when the plane is out of the parking Ineffective use of the passenger door

3. Angle Nose-Out

It is an aircraft parking system in which the nose of the aircraft faces away from the terminal at a 45º angle to the terminal building.

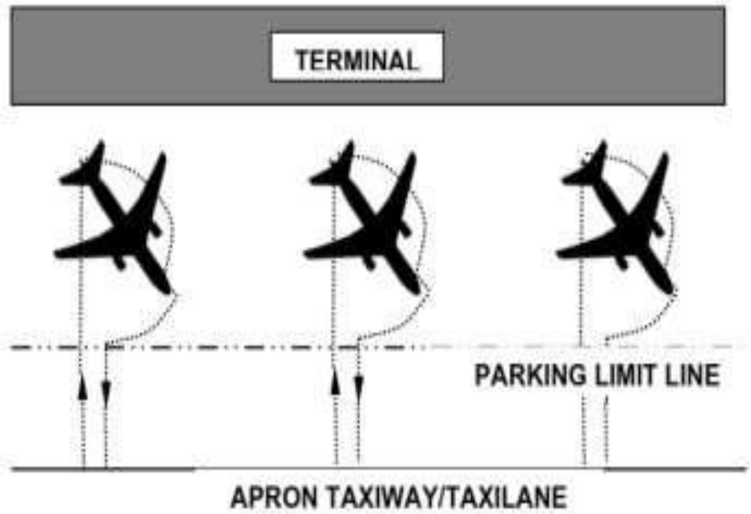

Figure 3. Angle nose-out parking

From the figure 3 above, obtain the advantages and disadvantages of the parking system, as follows:

Table 3. Advantages and disadvantages of nose-out parking

Advantage	Disadvantage
No pull tool is needed when the aircraft exits from the apron	Requires apron area which is larger than the Angle Nose-In type
	There is noise from the aircraft engine when the plane is out of the parking Ineffective use of the passenger door

4. *Parallel*

An aircraft parking system that is parallel to the terminal building.

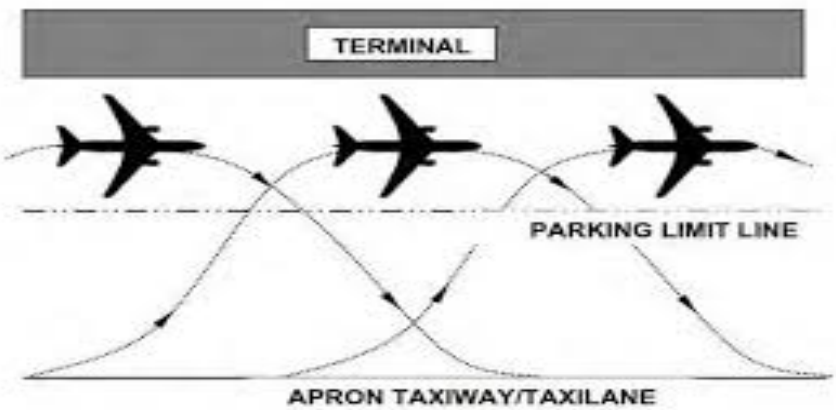

Figure 4. Parallel parking

From the figure 4 above, obtain the advantages and disadvantages of the parking system, as follows:

Table 4. Advantages & Disadvantages of Parallel parking

Advantage	Disadvantage
No pull tool is needed when the aircraft exits from the apron It's easier to steer the plane when entering/exiting Penggunaan pintu pesawat lebih efektif	Requires a very large apron area, more than other types. Airplane service activities are very close to other airplanes

2.4. *Marshaller*

Marshaller is someone who gives orders to airplane pilots to park their giant vehicles when the airplane lands on the runway. A marshaller must be correct and precise in giving signals to the pilot. Because to park an airplane that has a large size, you have to be careful, you can't be careless in the slightest.

Aircraft Marshalling is visual signaling between ground personnel and pilots on an airport, aircraft carrier, or helipad. Marshaling is one-on-one visual communication and a part of aircraft ground handling [8]. It may be as an alternative to additional to, radio communications between the aircraft and air traffic control. The usual equipment of a marshaller is a reflecting safety vest, a helmet with acoustic earmuffs, and gloves or marshaling wands–handheld illuminated beacons.

Figure 5. Marshaller hand signal

At airports, the marshaller signals the pilot to keep turning, slow down, stop, and shut down engines, leading the aircraft to its parking stand or to the runway. In this design, the instructions used are only instructions to turn right, left and stop and give a signal to the pilot that the aircraft is on the center line with the specified parking line.

2.5. *Visual Guidance Display*

Visual Guidance Display System is the equipment that guides aircraft visually to the parking lot on the Apron automatically. This guidance system is designed to provide fast, smooth, and precise docking guidance to the gate terminal. The Frequency Marker controls the aircraft type to ensure that it matches the information provided for docking [9]. It displays clear and visible information to the pilot on a high-intensity LED display for correct docking directions.

The docking procedure can be faster by using automatic docking than using a marshaller. Parking without using a marshaller will be more effective because the use of a marshaller will be constrained during bad weather and allow the same staff to handle other tasks on the apron, as well as minimize the movement of the number of airport officers working around the apron for safety reasons.

2.6. *Basic Concept Visual Guidance Display*

The basic concept of VDGS is as follows: The sensor used is an ultrasonic sensor of the type SRF04 (a sensor that doesn't emit visible light, so it's safe for the eyes (pilot). This sensor will send a spectrum of light beams that will hit the fuselage, the reflection of this spectrum will returned to the receiving sensor, after which the sensor circuit is connected by the data sender [10].

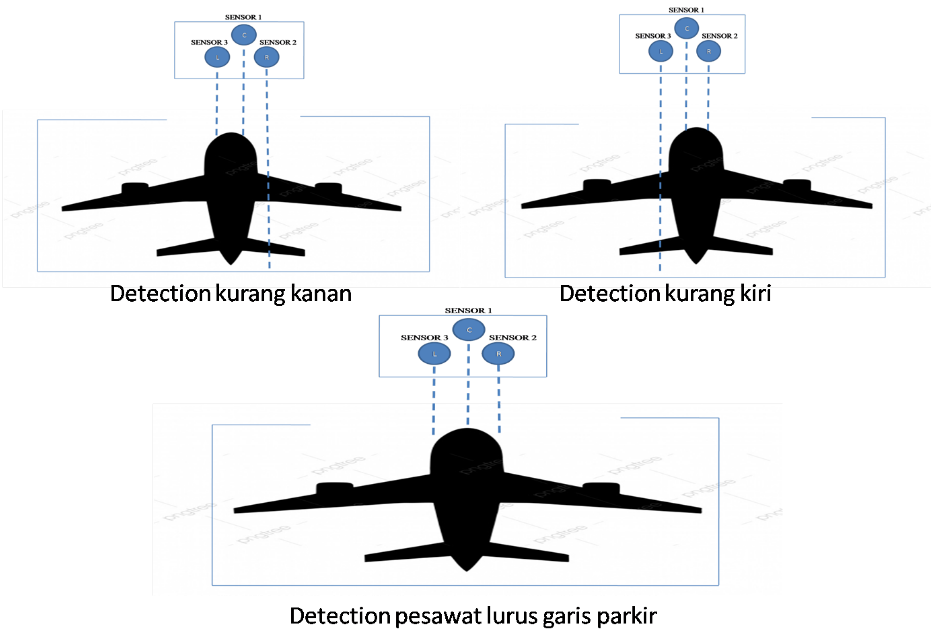

Figure 7. Basic concept of visual guidance display

The data that is read by the sensor will be sent and the receiver will connect the received data by connecting to the dotmatrix LED, the dotmatrix will display the characters according to the position of the aircraft.

2.7. Display Module

Display "standby"

It's display when the aircraft parking position is empty, showing the number of available parking spaces.

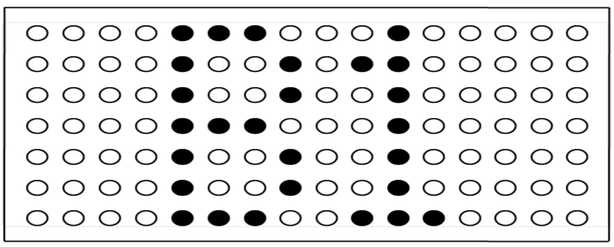

Figure 8. Display "Standby"

Straight signal indicator

The LED light up indicates that the aircraft is in a straight line, as shown in the figure below:

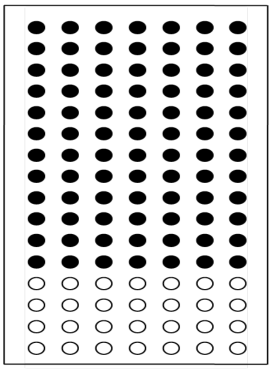

Figure 9. Airplane's position in a straight condition

Tracking

When the aircraft's position has been captured by the frequency, the movement of the aircraft will be displayed by the LED monitor [10]. If the arrow shows the right direction, the pilot must direct the aircraft to the right as shown below:

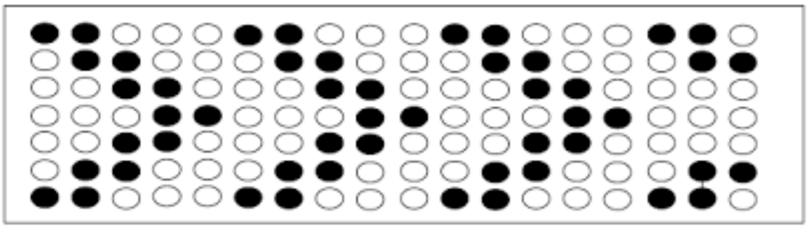

Figure 10. The aircraft indicator is too left

If the arrow points to the left, the pilot must steer the aircraft to the left

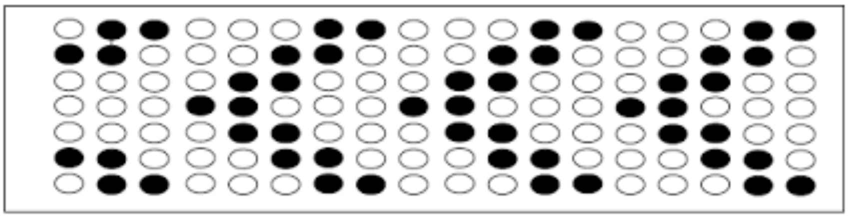

Figure 11. The aircraft indicator is too right

If the plane is in the center line or is straight against the parking line, the display shows the calculation of the distance which the pilot must stop the plane.

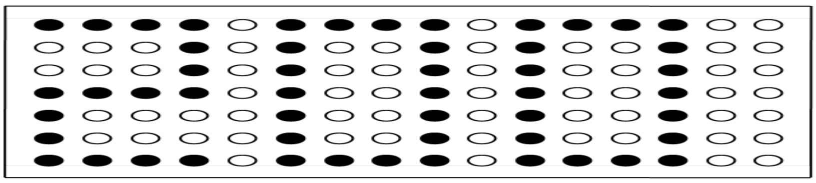

Figure 12. Distance indicator

Stop Position

When the position of the aircraft has reached the area where it must stop or the position has been reached [11], the screen will display the STOP command.

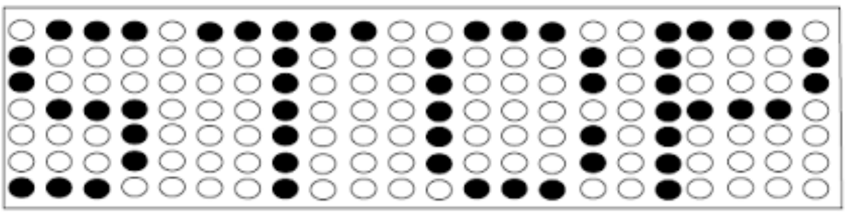

Figure 13. Stop sign

3. RESULTS AND ANALYSIS

The material to be discussed is a block diagram of the entire system from a design to testing.

3.1. Diagram Block System

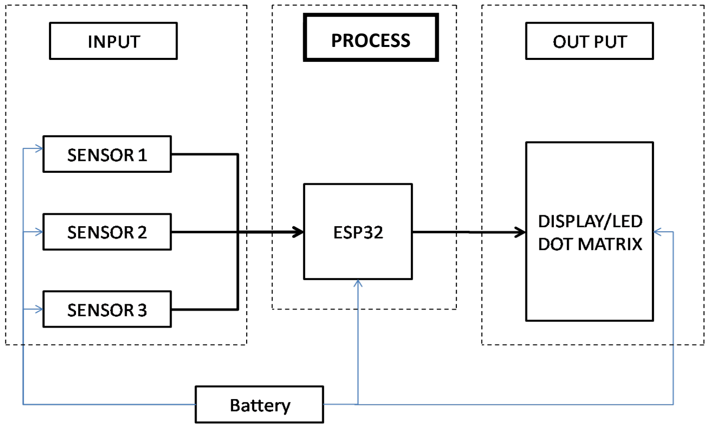

Figure 14. Diagram block system

From the description of the diagram block Figure 10 above, it explains how it works.

a. Aircraft sensor block

In this block, there are 3 (three) sensors that can determine the position of the aircraft where the sensor position will be adjusted to the configuration dimensions of the aircraft model which is going to be parked.

b. Block of controller (Proses).

In this controller block, it is the main brain of the tool that will be made. In this case, the ESP32 module is used as the main control of the tool.

c. Block of Display (Output)

The display block is a part that will display the data obtained from the ESP32 module so that it displays a LED Dot Matrix as a parking direction.

3.2. The Entire of The Principal Work

The work principle is the workflow of the tools and the systems that you want to create, from the description of the working principles of the tool that has been created, will make it easier to design and manufacture the tools and systems that are made. So, one, two, or three closed sensors are as an input that will be displayed on the parking display. For this reason, a schematic of the work of the tool to be made can be seen in the figure below.

a. Sensor detection position when the aircraft is too far to the left, and slightly or less to the right

In this case, the sensor that gives an input is a sensor that is covered by object so that it produces a command output for the display that is displayed. For example, if Sensor L (left) and Sensor C (center) or one of the sensors is covered by the aircraft, then the display will bring up a command "less to the right", so the aircraft must move slowly to the right to park in the right position, means its position is equal to the parking line (center).

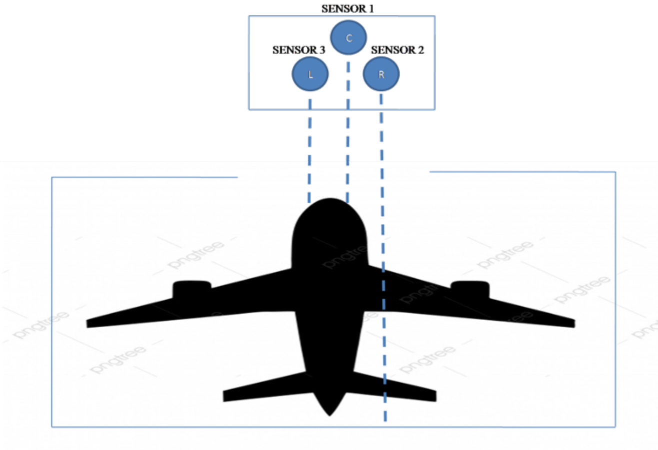

Figure 15. The position of the Aircraft is too far to the left

b. Sensor detection position when the aircraft is too far to the right, or less to the left

In this position, the sensor that gives an input is a sensor that is covered by object so that it produces a command output for the display that is displayed. For example, Sensor R (Right) and Sensor C (center) or one of the sensors is covered by the aircraft, the display will give a command “less to the left”, so the aircraft must move slowly to the left, so its position is equal to the parking line (center).

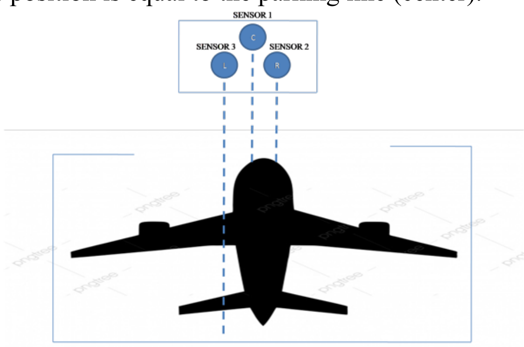

Figure 16. The aircraft’s position is too far to the right

c. Position sensor detection when the plane is straight against the parking line

In this situation, all sensors are covered, it indicates the position of the aircraft is in a straight line of parking, which all sensors, Sensor L(left) Sensor R (Rights) and Sensor C (center) are covered by the aircraft, the display will show a command “ stop”, means it has approached the specified distance when parking.

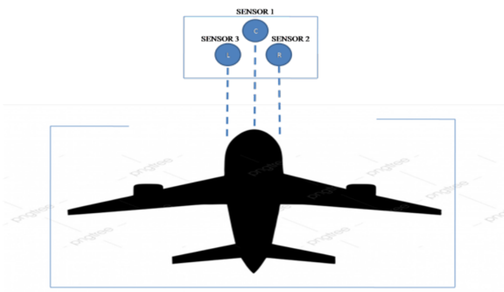

Figure 17. The straight / center position

3.3. Testing And Analysis

After designing and making tools, the next step is testing and analyzing the tools that have been made, so that the objectives of the design are as expected.

a. Proximity Sensor Testing and Analysis by a Ruler on the Objects

In this test, it’s commited by measuring the distance with the proximity sensor and the ruler on a flat object, which is placed in front of the proximity sensor. That experiment was carried out to ensure that the sensor used is precise on the object in front of it before being used for a series of tools. Figure illustration of the object’s location to the sensor and ruler, as below:

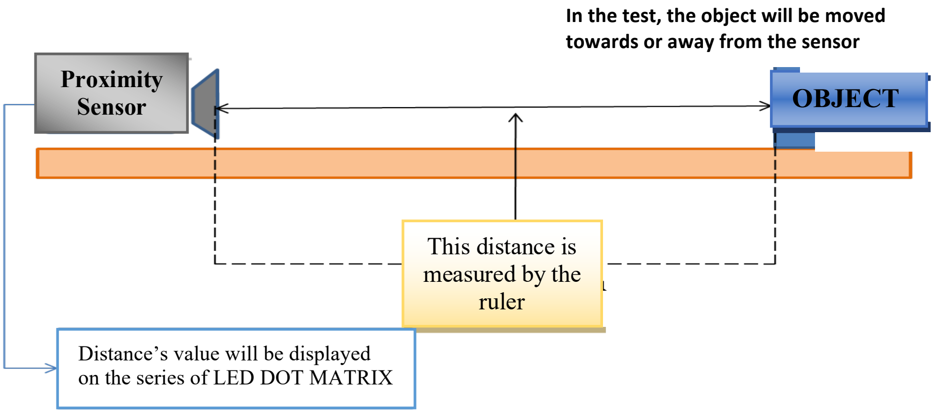

Figure 18. Proximity sensor test scheme

From the test schematic above, the data is obtained in the form of a table, as follows:

Table 5. Table of measuring object distance to sensor

No	Ruler Measurement Results (cm)	Center Sensor Measurement Results (cm)	Error Difference	Success (%)
1	50	50.12	0.12	99.76
2	45	45.03	0.03	99.93
3	40	40.05	0.05	99.88
4	35	35.09	0.09	99.74
5	30	30.04	0.04	99.87
6	25	25.02	0.02	99.92
7	20	20.01	0.01	99.95
8	15	14.98	0.02	99.87
9	10	10.3	0.3	97.00
10	5	5.4	0.4	99.20
		Average	0.072	99.51

To get the result of the error difference on the table above, the following formula used:

$$\textit{Error difference} = \textit{ruler measurement result} - \textit{sensor measurement result} \quad (2)$$

And to get the success percentage rate, the formula used is as below:

$$\%\ \textit{succes} = \frac{(\textit{ruler result} - \textit{error difference})\ x\ 100\%}{\textit{Ruler measurement result}} \quad (3)$$

From the table of measurement results obtained, the average of error difference between the results measured by the proximity sensor and the results measured by the ruler is 99.51% which can be concluded that the accuracy of the proximity sensor is 99.51% because the success rate of the sensor accuracy is satisfied, then the sensor is feasible to use to continue assembling this tool.

b. Testing and Analysis Tools

It's the test for the tools that have been made, including circuit testing, ESP32, and proximity sensors.

Proximity Sensor Test

This test aims to obtain accurate sensor data on the aircraft with the results obtained by the proximity sensor and by displaying the distance value on a serial Led Dot Matrix display. From this data, a sensor accuracy result will be obtained an accuracy result and be commited a test on various aircraft's positions during the parking process. For testing the proximity sensor is grouped into several sections, as follows:

a) Proximity Sensor Testing when the plane is less to the right.

In this experiment, the sensor L & C or from one of the sensors should be conditioned closed by the fuselage. The test is to ensure how maximum distance of the sensor to detect early when the aircraft is caught by the sensor in the condition of the aircraft is less to right (not in center/ straight line parking).

Table 6. Maximum distance measurement L and C sensor (45cm)

Test	Distance On Display	Sensor Distance Measurement Results (Ruler)	Error Difference	Presentation Success
1	45	45.03	0.03	99.93
2	40	40.05	0.05	98.77
3	30	30.04	0.04	99.86

And to get the success percentage rate, the formula used is as below:

$$\% \textit{ succes} = \frac{(\textit{ruler result} - \textit{error difference}) \times 100\%}{\textit{Ruler measurement result}} \quad (4)$$

b) Proximity Sensor Testing when the plane is less to the left.

In this experiment, the R & C sensor or from one of the sensors is conditioned to be closed by the fuselage where this test is to ensure the maximum distance the sensor detects early when the aircraft is caught by the sensor in the condition that the aircraft is not right.

Table 7. R and C Sensor Maximum Detection Distance Measurement (45cm)

Test	Distance On Display	Sensor Distance Measurement Results (Ruler)	Error Difference	Presentation Success
1	45	45.30	0.30	99.33
2	40	40.02	0.02	99.95
3	30	30.04	0.04	99.86

c) Proximity Sensor Testing when the plane is in the center line of the parking lot.

In this experiment, the R, L & C sensors are conditioned to be closed by the fuselage where this test is to ensure the maximum distance the sensor detects early when the aircraft is caught by the sensor when the aircraft is not to the right.

Table 8. R L & C Sensor Maximum Detection Distance Measurement (45 cm)

Test	Distance On Display	Sensor Distance Measurement Results (Ruler)	Error Difference	Presentation Success
1	45	45.05	0.05	99.88
2	40	40.04	0.04	99.90
3	30	30.06	0.06	99.80

4. CONCLUSION

The design of the practicum module is successful in accordance with the results of system testing between programming with installed sensors and the navigation system that is built can run according to the design. The proximity sensor is not affected by transparent objects such as glass, this is because the proximity sensor uses ultrasonic signals, so the ultrasonic signal will be reflected back by the object and received back by the sensor.

If the distance between the Sensor & Object is less than 45cm, the ultrasonic sensor works well with an average accuracy percentage of 99.51% taken from each experimental instrument so that the module can be used according to the procedure.

5. ACKNOWLEDGEMENTS

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