Development of Training Kit Basic Aerial Robotics Using RC Plane Robot for Robotics Course

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Abstract. RC Plane Robot and basic aerial robotics are technologies that are widely used, so training kits are needed to learn them. This study aims to: (1) Design and build, (2) Test performance and (3) Determine the feasibility level of training kit basic aerial robotics using RC plane robot. The study used the Research and Development method with the following procedures: (1) Potential and problem, (2) Data collection, (3) Design, (4) Validation, (5) Revision and (6) Trial. The object of the research is the RC Plane Robot training kit and the practicum jobsheet. The research subjects were students of the Electronic Engineering Education Study Program, Faculty of Engineering, Universitas Negeri Yogyakarta. The results of the research are in the form of hardware and practicum jobsheet. The hardware part consists of a robot plane, a work area (Box) and a remote control. The level of feasibility of training kits by material experts gets a percentage of 91%. By media experts get a percentage of 89.5%. By respondents (students) get a percentage of 86%. Based on these results, the training kit basic aerial robotics using RC plane robot is very feasible to be applied to the Robotics course.

1. Introduction
The development of the role of robots in the industrial world is currently increasing along with the times. Robot is a mechanical device that can do work like humans or behave like humans [1]. In the industrial sector, the technology used is developing so fast. Because of this, RC Plane Robots are widely used in the Unmaned Aerial Vehicle (UAV) industry to activate human activities in carrying out various tasks/missions. The application of the RC Plane Robot is used to find victims when there is a disaster, make maps for geographical purposes and be able to observe many areas or extensive agriculture from aerial monitoring and so on [2]. The development from time to time that is rapidly accelerating makes the function or use of UAV technology increasingly widespread, from its initial function only being used to assist military defense [3].

In order to support the operation of the RC Plane Robot, of course it is very necessary to know and understand the various uses of technology and the characteristics of the RC Plane Robot used. Based on this, it further strengthens that it is necessary to study various applications of the use of technology, especially in the industrial world that develops from time to time. Therefore, HR (Human Resources) to support this is needed. The way to improve competence and learn about the development of industrial technology that is always evolving is with a training kit [4].

In the robotics course, the Department of Electronics and Informatics Engineering Education, Universitas Negeri Yogyakarta teaches several topics of discussion regarding the field of robotics.
Based on observations, information data was obtained, namely the absence of a training kit that supports the basic material for the application of aerial robotics systems that are applied especially to airplanes. This causes students not to be able to know the application and basic material of aerial robotics applied to aircraft, thus causing the lack of achievement of aerial robotics competence. These competencies are 1) understand the servo configuration on 3-axis arm-base and elevons motion control, 2) understand how to control the speed of brushless DC motor, 3) understand how to communicate data wirelessly using NRF24L01, 4) understand the basic motion of plane robot flying wing. These four competencies packaged in single training kit as a RC Plane Robot.

Based on description above, the several problems can be identified are 1) lack of supporting training kit devices of competence to understand about servo configuration, understand how to control brushless DC motor, understand how to communicate data using NRF24L01, and understand the basic motion of plane robot, 2) the four aerial robotics competence on above has not yet been achieved, 3) there is no supporting training kit, causing students not to be able to know the application and basic material of aerial robotics applied to plane robot. This study aims to 1) Design and build, 2) Test performance and, 3) Determine the feasibility level of training kit basic aerial robotics using RC Plane Robot.

Aspects that include psychomotor, cognitive, and affective aspects can be applied by the use of assistive devices/training kits during the learning process [5]. The training kit has the same function or role as the learning media. Some of the roles of using learning media during the practicum process include 1) facilitate learning, 2) provide real experience, 3) learning becomes less boring and more fun, 4) activate all the senses of students as well as, and 5) attract the attention of students [6].

RC Plane Robot is an Unmanned Aerial Vehicle (UAV) type robot that can fly without a pilot inside it [7]. RC Plane Robot is an unmanned aircraft, in which the only method of take-off and landing is horizontal (HTOL) [8]. This research uses flying wing type aircraft. Flying wing is a fixed-wing aircraft with no definite fuselage [9]. The main control to move the RC Plane flying wing type is the thrust and elevons that provide aerodynamic strength so that the aircraft can follow the desired flight path. Thrust is a mandatory input for every movement [10]. Every movement of the RC Plane Robot has its own term. Pitch is a term for the movement up or down the nose of the aircraft. Roll is a term for the movement of tilted to the right or tilted to the left of the aircraft. In addition there is also a movement to turn right or turn left, this movement can be called yaw [11].

2. Methods
The research is carried out using a development model by means of R&D or Research and Development. The stages of the development procedure carried out using six steps, including 1) Potential and problem, 2) Data collection, 3) Product design, 4) Product validation, 5) Product revision and 6) Product trial [12]. The research method used to produce a particular product and used to assess the effectiveness of the product is called R&D or Research and Development [12]. All these stages are shown in the image below:

![Figure 1. R&D model [12]](image-url)
2.1. Time, location, data collection and analysis
The implementation process of the research was carried out in the month of May 2021. This research was conducted at the Department of Electronics and Informatics Engineering Education, Universitas Negeri Yogyakarta. The object under research is the Basic Aerial Robotics Training Kit using an RC Plane Robot Based on an Arduino Microcontroller and supported by a practicum jobsheet. The research subjects are material expert lecturers and media expert lecturers with the role of evaluator. In addition, there are also students of the Electronic Engineering Education Study Program who have taken robotics courses.

The process of collecting research data through measurement can use a tool called an instrument [13]. Questionnaires, graded scales, tests, interview guides, observation guidelines, and checklists are types of instruments [14]. In this research, data collection was carried out by observation and distributing questionnaires with consist of 4 choice answer using a Likert scale to material expert lecturers, media expert lecturers and students who in this case acted as respondents. Due to the Covid-19 pandemic, the observation and data collection was carried out online using a google form.

The data analysis technique in this study is a quantitative descriptive analysis technique, which serves to determine the feasibility level of the training kit. The use of this analytical technique can analyze and present the data obtained so that it becomes communicative and meaningful [15]. Determination of the feasibility level of the training kit is done by weighting the answer scores from the questionnaire filled out by lecturers and users. The weighting of the scores is described in the following table:

| Criteria         | Score |
|------------------|-------|
| Totally Agree    | 4     |
| Agree            | 3     |
| Disagree         | 2     |
| Totally Disagree | 1     |

Table 1. Questionnaire score criteria

In order to produce the average value of the feasibility of the training kit, the following formula is used:

\[
\bar{X} = \frac{\sum \text{rater score}}{\text{number of respondents}}
\]  

(1)

How to get the percentage of the average calculation results in order to determine the feasibility of the training kit is determined by the formula below:

\[
\text{Feasibility (\%)} = \frac{\text{observed score}}{\text{maximum score}} \times 100\%
\]  

(2)

To find out the level of feasibility based on the percentage of feasibility obtained using a rating scale benchmark. The rating scale benchmark serves to convert quantitative data to qualitative data [16]. The feasibility percentage category shown in the following table:

| Feasibility (%) | Category     |
|-----------------|--------------|
| >75 - 100 %     | Very Feasible|
| >50 - 75 %      | Feasible     |
| >25 - 50 %      | Unfeasible   |
| 0 – 25 %        | Very Unfeasible|

Table 2. Feasibility percentage category
3. Results and discussion

3.1. Training kit design
This training kit is designed for learning about the movement of flying wing aircraft. Therefore, there is a 3 Axis arm which functions to simulate the movement of pitch, yaw and roll. This 3 Axis arm is placed just below the plane robot. We get the 3 Axis arm design in Figure 3 based on the principle of movement on the plane robot flying wing type in Figure 2.

![Figure 2: Principle of movement plane robot flying wing type](image)

![Figure 3: 3 Axis arm to simulate the movement](image)

Plane robot and 3 axis arm are controlled wirelessly via remote control. On the remote control there are two joysticks, where the left joystick functions to adjust the speed of the brushless motor (throttle). The joystick on the right is used to control the movement of the aircraft. This training kit has a design in diagram block like following below:

![Figure 4: RC plane robot block diagram](image)

The working principle is, the pilot sends a signal from the remote control (transmitter) to the receiver on the plane, then the receiver gives orders to the servo and brushless motor on the plane to move according to the pilot's wishes. The principle for controlling aircraft movement is identical to the control on conventional aircraft, namely using a propeller to push the plane so that it moves forward, and using the control surface (elevons) to maneuver. Because of training kit is designed for learning about the movement of flying wing aircraft, then the speed of brushless motor are limited only 15%, it's for safety.
A complete design training kit in the form of a robot serves to provide students with real application experience of aerial robotics on RC plane robots. In the development of the RC Plane robot training kit, it is also equipped with a jobsheet. The practicum jobsheet can be used as a guide for students as well as helping lecturers to teach aerial robotics material on the RC Plane Robot.

Figure 8. Practicum jobsheet

3.2. Training kit performance
The performance of the training kit was tested by testing the angle of each arm axis (Roll, pitch, yaw), Tx-Rx communication and correlation between joystick position with robot movement.

3.2.1. 3 Axis arm testing. The 3 Axis arm testing aims to determine angle movement that produced by servo motor that can be found in each arm axis. Testing is done by giving the PWM value for the default position. The default angle position is 90 degree for each axis. To measure the result of angle movement, we use bow. The testing result of 3 Axis arm is shown in the following table:

Table 3. Testing result of 3 axis arm

| Servo | Axis | Angle Result Each Axis (degree) | Error (%) |
|-------|------|---------------------------------|-----------|
|       |      | Trial 1 | Trial 2 | Trial 3 |       |
| 1     | Z (Yaw) | 96 | 98 | 94 | 6,67 |
| 2     | X (Roll) | 83 | 93 | 85 | 3,33 |
| 3     | Y (Pitch) | 90 | 89 | 93 | 0,74 |

Based on the result above, there are contains error in measurement of x, y and z axis. This error caused by design mechanic less precise and contains friction especially for x and z axis. Besides that, it caused by offset servo value and manual measurement using a bow resulting error.

3.2.2. Tx and Rx communication. The Tx and Rx communication testing aims to determines the performance of NRF24L01 in sending analog data from the joystick on the remote controller and receiving that data on the plane robot. The testing result of Tx and Rx communication is shown in the table 4.

Table 4. Testing result of Tx and Rx communication

| Trial | Transmitter CH 1 | Transmitter CH 2 | Transmitter CH 3 | Receiver CH 1 | Receiver CH 2 | Receiver CH 3 | Error (%) | Delay (ms) |
|-------|------------------|------------------|------------------|---------------|---------------|---------------|-----------|-----------|
| 1     | 76               | 124              | 121              | 76            | 124           | 121           | 0         | 1         |
| 2     | 122              | 50               | 220              | 122           | 50            | 220           | 0         | 3         |
| 3     | 250              | 180              | 75               | 250           | 180           | 75            | 0         | 1         |
Based on the result that shown in table 4, it shows that the NRF24L01 module, both transmitter and receiver, is able to send and receive data properly in each channel without contains error. No noticeable latency. Testing from anywhere in the practicum room with 1-10 meters distance (with thick walls and lots of wifi networks around) results in 1-3ms lags with nothing data loss.

3.2.3. Correlation between joystick position with robot movement. Changes in the position of each joystick on the remote controller will cause movement effects on the 3 Axis arm simulation, control surface (elevons) and position of the plane robot. That correlation is shown in the following table:

| Input                  | Output                                      |
|------------------------|---------------------------------------------|
| Left Joystick          | Right Joystick                              |
| Move Up                | -                                           |
| Move Down              | Move Up                                     |
| -                      | Move Down Down                              |
|                        | Move Left                                    |
|                        | Move Right                                   |
|                        | Move Left & down                             |
|                        | Move Right & down                            |
| Elevons Left           | Down                                        |
| Elevons Right          | Up                                           |
| Robot Movement         | Down                                         |
| More throttle (forward)| Nose down                                    |
| Less throttle (silent) | Nose up                                      |
| Tilt to the left       | Tilt to the right                            |
| Turn to left           | Turn to right                                |
| Turn to right          |                                             |

3.3. Training kit feasibility level

The feasibility level of training kit product is carried out by material experts, media experts and users (students). Feasibility level is described below:

3.3.1. Based on material expert. The assessment carried out covers the quality aspect of the material and its expediency aspect. The quality aspect of the material contains 6 parameters which include 16 assessments. For expediency aspect contains 2 parameters that include 4 assessments. Maximum score from all aspects is 80 and minimum score is 20.

![Feasibility Percentage of Material Expert](image)

The result of the assessment by one material expert on graphic figure 9, feasibility of material quality aspect get percentage score 93%, feasibility of expediency aspect get percentage score 88% and total of average score is 91%. Besides that, material expert giving feedback to apply other robotics...
topics for next studies on this training kits, example: stability system, graphic user interface, or etc. to get completely good material.

3.3.2. Based on media expert. The assessment carried out covers the quality aspect of the display, technical quality aspect and its expediency aspect. The quality aspect of the display contains 4 parameters which include 9 assessments. For technical quality aspect contains 3 parameters that include 7 assessments. For expediency aspect contains 4 parameters that include 8 assessments. Maximum score from all aspects is 96 and minimum score is 24.

![Feasibility Percentage of Media Expert](image1)

**Figure 10.** Feasibility percentage graphics of media expert

The result of the assessment by one media expert on graphic figure 10, feasibility of display quality aspect get percentage score 88,9%, feasibility of technical quality aspect get percentage score 85,7%, feasibility of expediency aspect get percentage score 93,8% and total of average score is 89.5%.

3.3.3. Based on users (students). The assessment carried out covers the quality aspect of the display, technical quality aspect, material quality aspect and its expediency aspect. The quality aspect of the display contains 4 parameters which include 9 assessments. For technical quality aspect contains 3 parameters that include 6 assessments. For material quality aspect contains 3 parameters that include 6 assessments. For expediency aspect contains 4 parameters that include 8 assessments. Maximum score from all aspects is 116 and minimum score is 29.

![Feasibility Percentage of Users (Students)](image2)

**Figure 11.** Feasibility percentage graphics of users (students)

The result of the assessment by users (students) on graphic figure 11, feasibility of display quality aspect get percentage score 86%, feasibility of technical quality aspect get percentage score 85%, feasibility of material quality aspect get percentage score 85%, feasibility of expediency aspect get percentage score 89% and total of average score is 86%.
4. Conclusion
From the research and discussions it can be concluded that, 1) the design of the training kit basic aerial robotics can be well developed by using the RC Plane Robot in the form of tools and practicum jobsheet, 2) in the performance test of the training kit, each axis on the 3 axis arm can simulate various basic movements of a flying wing type robot aircraft. Each axis can move with an error percentage x of 3.33%, y of 0.74% and z of 6.67%. The control surface and brushless motor can be controlled using a remote control wirelessly without contains error, 3) the feasibility level of the training kit based on the assessment of material expert lecturers gets an average score of 91% (very feasible), based on media expert lecturers gets an average score of 89.5% (very feasible) and based on users (students) gets an average score of 86% (very feasible). Based on these results, the training kit basic aerial robotics using RC plane robot is very feasible to be applied to the Robotics course. As a future improvement, to provide a complete topic on the study of robotics, using a stability system or Graph User Interface (GUI) can get good material. In addition, by using the GUI, the system will be communicative.

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