Design of Robot Plotter Software for Making Pattern with Turtle Graphics Algorithm

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Abstract

Robot plotter can be more practical with a turtle graphics algorithm-designed interface application. Here is a literature review to develop a plotter robot control model. An experiment constructed software to transmit interface and robot plotter commands. Robot plotter uses selective compliance articulated arm (SCARA) on two x and y joints. A Turtle Graphics application commands the plotter robot to make batik design. A plotter robot can create a simple batik pattern on paper. Combining the writer's electrical engineering and art knowledge created a distinctive interface. This is new research. Research improves education and industry. The study helps automate batik pattern making. For those with disabilities, research can help them make patterns.

Keywords: Robot Plotter, Turtle Graphics, Graphics Algorithm.

1 Introduction

Robot Plotter XY is a robot that creates large images. It utilizes vector graphics and is controlled by the Arduino Uno microcontroller and the open-source software platform Arduino Idea. The robot receives input from a computer through the Arduino server-based program Polagraph, and uses processing software version 1.0.5, which includes the Polar graph Libraries, to begin sketching on a drawing board or piece of paper. The XY plotter has two axis control, x and y, and a mechanism for raising and lowering the pen. Each axis is moved by a single servo motor and the pen is controlled by another servo. The flexibility of the pen is managed by two stepper motors located on the corners of the board or paper sheet, which allows the robot to work at a fast pace and with increased precision [1, 2].

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XY Plotter is a system that is integrated into a device and operates on the principles of computer numerical control. The plotter uses two stepper motors and servo motors to input data from a computer onto a drawing board, controlled by the ATmega328P microcontroller on the open-source physical computing platform ARDUINO. This X-Y plotter robot focuses on vector graphic devices [3, 4].

Research has led to the implementation of a 2D plotter robot that utilizes a selective compliance articulated robot arm (SPA). This robot plots on a drawing board based on input given by a computer, controlled by the ATMEGA 8 microcontroller on the open-source physical computing platform Arduino. This robot, known as Scara, is a self-governing arm that has three degrees of freedom and two flexible connections on the XY axis, but a rigid connection on the Z axis. This design allows the arm to execute tasks quickly and with high precision [5, 6].

Plotters, being a type of CNC machine, require high precision in their processes. Therefore, during their production, all details that may cause errors in plotting a vector must be taken into account. These errors can be caused by damaged electro-mechanical components, poor calibration of mechanical elements, or mistakes made in the programming process. This paper details the mechatronics process that connects electronic components and machines to create compact, portable, and precise machines that can replace human tasks such as writing, drawing, and carving. The solution presented will have low production costs, and its small size and portability will make it useful in everyday life [7, 8].

The design of software architecture is crucial for the success or failure of any software system, as it pertains to the basic structures, subsystems, and interactions between them. Software architects act as decision makers, evaluating potential solutions to system design problems and selecting the most optimal option. These architectural decisions involve discussing system requirements, including functional and quality aspects. This article presents the results of a systematic literature review (SLR) that aims to assist architects in the decision-making process by connecting quality attributes with software patterns [9].

Commands that can be done by the plotter robot by giving commands in the form of logic thinking about the direction and angle will be relatively easier, with the visualization of the movement of a robot that can advance, backward, turn left - right according to the intended angle by drawing a line sign Through it, so that the direction and angle. The pen is regulated so that it can be removed not to make a line (pen up) or lowered (pen down) to make a line.

2 Literature Review

Arduino is an open-source platform used to design and control electronics. It allows for communication with a variety of devices, including those connected to the internet. The platform utilizes the Arduino Uno Circuit Board and a C++ based Software Program to program the boards. Due to its user-friendly interface, Arduino is commonly used in microcontroller programming. Like other microcontrollers, it is a circuit board with a chip that can be programmed to perform various tasks. It receives information from computer programs and sends it to the microcontroller, which then sends commands to a specific circuit or machine with multiple circuits. Arduino can also read input from devices such as sensors, antennas, and potentiometers and send information to output devices such as LEDs, speakers, LCD screens, and DC motors[10].

The use of the Sram Puff microcontroller is important due to its physical un-clonable function (PUF), which utilizes material directly from the device manufacturing process. One example of this is the Sram-PUF. Storing keys securely is a common issue, and typically involves creating and storing the key in non-volatile memory (NVM). The Sram-PUF uses the ignition status of Sram cells to generate IDs/keys. In this paper, we propose the implementation of the SRAM PUF on the microcontroller using the internal Sram block. By combining it with a simple error correction code, such as the repetition code, we can reduce the error rate to a minimal level. By using a repetition factor of 31, the probability of one or more errors in the 2048-bit key is lower than 7E-7 in the temperature range from 0C to 80C. The low cost and ease of implementation make the Sram-PUF on the microcontroller a desirable option for general use [11].

One application for using ARM/plotter robots is the simulation of human signatures. Currently, signatures are becoming less common and difficult to transport, especially when distance is not a significant factor. They are repetitive tasks that consume a lot of time in various daily activities. The goal of the paper and products discussed is to develop effective and authentic systems that replicate human handwriting. The unique feature allows users to be near or far from the machine, while the writing is stored in their account, resulting in significant time savings [12].

Research that was conducted by [13], namely the design of the Arduino Microcontroller - based electronic circuit printing device. This tool works by displaying images on the work desk following the code received by Arduino called G-Code, which was previously in the form or extension of the image file from the Inkscape application and was converted by the Makercam application and then uploaded by the Xloader application and the movement was controlled by the Grbl Controller. From the test results, the Pen Plotter three axis based on the Arduino microcontroller can print simple electronic circuit pathways and various images through the Inkscape and Makercam applications.

Setioko B.T. conducted research that resulted in the design of a 2-dimensional plotter using CNC and Arduino Uno. The tests showed that the 2-dimensional plotter had an accuracy of 97.947% and precision of 99.985%. Additionally, it had a range of operation of 4cm with a resolution of 0.01cm [14].

Mukhofidhoh & Kholis N [15] conducted research on designing an automatic mini PCB drilling machine that can move in the x, y, and z directions through mechanical movements controlled by files sent through an Arduino Uno microcontroller to L293D motor drivers and servo motors. The test results showed that the PCB drilling machine can perform 200 drilling points within 1,770 seconds. This equates to an average of 6 drilling points per minute, due to the delay limit. The distance between points can detect movement with a difference of 1mm, with an average error rate of 2% for 100 distances produced and an average error of 1% for 200 drilling points.

The study conducted by[16] focused on designing a plotter machine that creates special linear and tilted lines on a flat surface. The design of the machine utilized an Arduino Uno as a signal reader and programming board, a stepper motor as a driver, a CNC shield as a connector for all components, and a servo motor as a ballpoint controller. The sketch was uploaded, sent to Universal G-Code Sender, forwarded to Arduino Idea, then to CNC Shield, and finally to the servo motor to control the movement of the ballpoint. The test results showed that the XY Plotter engine was successfully built with a special linear and tilted movement using the Arduino Uno, producing a special linear motion pattern created by alternating movement of the stepper X and Y motors and a special sloping movement created by the simultaneous movement of the stepper motor. The lines produced by the plotter machine are the same size as those programmed into the machine.

Next is the study that was conducted by Taufik M [17], namely implementing the ATMega microcontroller features, especially Arduino in the form of 2D printers with the principle of working utilizing the position control of two stepper motorcycles in the X-Y field and one Servo motorcycles in the Z field. The software used is ATMEL, WINVAVR, ARDUINO IDE as a compiler, while Inkscape and G-control as Gcode implementation, and graphic printers that can draw using a pen. From the test results, the 2-dimensional plotter has an accuracy of 97.947% and a precision of 99.985%. This 2-dimensional plotter can operate up to a distance of 4cm with a resolution of 0.01cm.

Due to the Covid-19 pandemic, most universities in Indonesia, including the Faculty of Engineering at Maranatha Christian University in Bandung, have had to shift their learning activities to be online. In recent years, engineering courses at this university have not included any content focused on developing emotional and humanistic values, which are essential for future practice. One solution adopted is the Fine Art Learning Program combined with mathematics, where students create batik motifs using turtle graphic algorithms in Python. The goal is to develop humanistic values in students. A questionnaire was distributed to 126 students, with 74% being male and 26% being female. The results showed that 55% of the students were interested in learning fine arts and turtle graphics to create batik motifs. The conclusion is that: 1) The creative function of the brain can be improved through learning with batik motifs; 2) Respondents who learn to make batik motifs interact better in their social environment; and 3) The ability to make batik motifs can be evaluated based on the shape, proportion and scale of the motifs created [18].

M. Aditi et al, [19] conducted research to develop robot arms that helps physically disabled people to write. The mechanism is a system of recognition of the user's speech programmed to write what is said. Robot arms are programmed to write the words spoken by the user or individual to the microphone. To carry out writing operations, the robot arm is installed with a pen.

Sindhuja R. et al, [20] developed a robot system to write and recognize speech [6] as an input from the user, which aims to help with dysgraphia people: disorders in writing skills, especially handwriting, and are transcription disabilities , which means writing disorders related to handwritten disorders, orthographic codes, and finger sorting (muscle movements needed for writing).

This research offers formal proof of the equivalence between fractal classes created by the Recursive-Turtle (RTP) and Iterated Affine Transformations (IAT) programs. It begins by reviewing the RTP (Geometric Interpretation of Non-Bracket L-systems with a single production rule) and IAT (iteration function system is limited to Affine transformation). Additionally, it presents a simple extension to the RTP that generalizes it from conformal transformation to arbitrary Affine transformation. The research also presents constructive evidence of the equality between fractal geometry produced by RTP and IAT, including a conversion algorithm between the two methods. The conclusion suggests possible extensions and open questions for future research [21].

3 Hypotheses Development

The main hypothesis of the embedded system and the basic mechanics of the robot can be integrated into a robot plotter. In general, the plotter robot can be controlled through a computer that is using RS232 serial communication and can be realized in the form of hardware or software with the right components and programming (Figure 1).

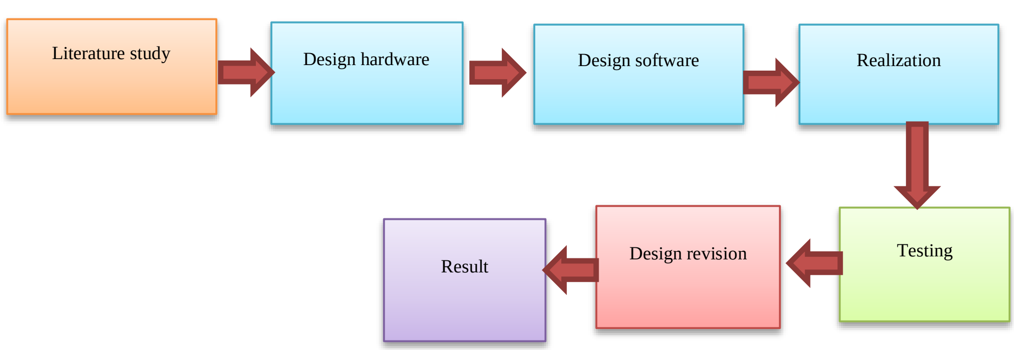


Figure 1: Diagram Block of Robot Plotter Research

Send data (filled in an instruction) and the send button is a feature for communication tests with a plotter robot. The instruction list is a feature to fill in a series of batik motif drawings with the Turtle Graphics function, the motif check button is a feature button to check the image results that will be plotted by the robot plotter and the process button is a feature button to send instructions to the robot plotter basis Wifi with TCP protocol.

4 Methodology

The main components of the plotter robot are microcontroller, drivers, stepper motor, wheels, and the body shape of the plotter robot with relatively small dimensions.

Figure 2 is the design of the plotter robot system block diagram that is done, the user (interacting) gives instructions through the computer wirelessly through WiFi with TCP protocol (in port 2022) to move the plotter as far as the specified direction to a certain position, the instructions are received by the Nodemcu ESP8266 -12 and translated into instructions to the Stepper Motor Controller (ULN2003 PCB), then the Stepper Motor Controller translated it into a step-pulse form, then the instruction /step pulse data was translated into movement on the motor stepper (28BYJ-48) to the x-axis position, the y-axis specified, while the rise/drop of the pen on the plotter robot is controlled through the SG90S servo motor.

The mechatronics process described here allows the creation of portable and precise machines that can replace human labor in tasks such as writing, and drawing are as follows: first determine the drawing, writing or engraving design to be made, then use algorithm turtle graphics to create commands that can form images, writing or carvings. The turtle graphics command will be given to the stepper motor to set the direction of the wheel motion on the x-axes or y-axes. Wheel movement can only be done on one axis.

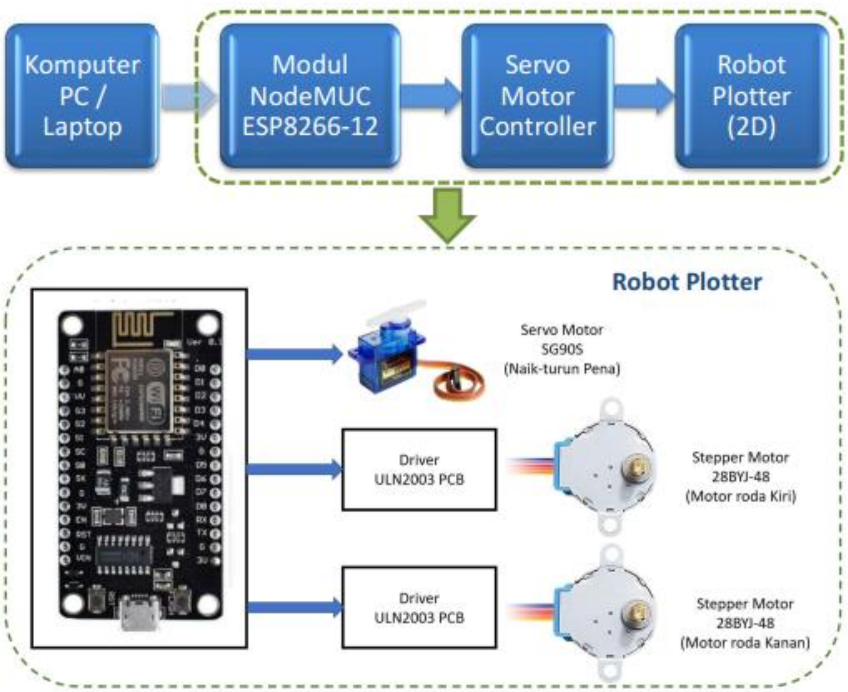


Figure 2: Block Diagram Robot Plotter System

The software is designed (using Visual Basic programming language) with a communicative interface feature (see Figure 3), users are provided a list of instructions where to write down robot movements with instructions according to the Turtle Graphics algorithm (forward, backward, backward turn left, turn right, rise, pen down) to draw in accordance with the pattern of thinking logic plot, after that can be done by pressing the "Check Image" button, the image simulation will be seen in the green box area, if it is considered true the user remains Pressing the "Process" button to be sent to the plotter robot for execution, the "send" button feature is also provided to send one instruction written in the send data to the plotter robot, the break button feature is provided if it will cancel the command when the instruction list takes place executed.

The process of giving instructions to the plotter is carried out through the user interface by writing commands as shown in Table 1, these commands will be sent to the Node MCU microcontroller via WiFi communication with the TCP protocol, to drive the stepper motors, and the stepper motors connected to the wheels will control the movement of the wheels.

For example, the command forward (10) with the turtle graphics command, is typed into the user interface menu as shown in Figure 3, the command will be parsed between instructions and parameters, so the command can be seen as follows:

Parsing

```
int pospasi = datastr.indexOf('('); // search char ‘(‘ position
String opcode = datastr.substring(0, pospasi);
int operand = datastr.substring(pospasi + 1).toInt();
```

execute forward instruction

```
if (opcode == "maju") {
//Serial.print("maju"); Serial.println(operand);
maju(operand);
}
```

Function for forward

```
void maju(float distance) {
  int steps = step(distance);
  //Serial.println(steps);
  for (int step = 0; step < steps; step++) {
    for (int mask = 0; mask < 4; mask++) {
      for (int pin = 0; pin < 4; pin++) {
        digitalWrite(L_stepper_pins[pin], rev_mask[mask][pin]);
        digitalWrite(R_stepper_pins[pin], fwd_mask[mask][pin]);
      }
      delay(delay_time);
    }
  }
  delay(jeda);
}
```

Instructions are translated into x-axis and y-axis movements

The pen-up control is managed in the same way as the forward command:

Parsing

```
int pospasi = datastr.indexOf('('); // search char '(' position
String opcode = datastr.substring(0, pospasi);
int operand = datastr.substring(pospasi + 1).toInt();
```

Execute penup instruction

```
if (opcode == "penanaik") {
    //Serial.println("penanaik");
    penanaik();
```

Function for penup

```
void penanaik() {
  penServo.attach(servoPin);
  delay(20);
  //Serial.println("PEN_UP()");
  penServo.write(PEN_UP);
  delay(500);
  penServo.detach();
}
```

Controlling the pen-up or pen-down is set in the same way as the forward command:

Parsing

```
int pospasi = datastr.indexOf('('); // search  char '(' position
String opcode = datastr.substring(0, pospasi);
int operand = datastr.substring(pospasi + 1).toInt();
```

Execute pendown instruction

```
if (opcode == "penaturun") {
    //Serial.println("penaturun");
    penaturun();
```

Function for pendown

```
void penaturun() {
  penServo.attach(servoPin);
  delay(20);
  //Serial.println("PEN_DOWN()");
  penServo.write(PEN_DOWN);
  delay(500);
  penServo.detach();
}
```

To draw patterns or sketches using turtle graphics, turtle graphics orders are made by following the line-side of the pattern and adjusted to a step forward, rotating left or right a few degrees, making lines or not making lines by pen-up or pen-down, and so on.

5 Results and Analysis

The interface is made as simple as possible (friendly user) as shown in Figure 3, so that the user is easy to use, the IP server and port number are filled by the IP and the Communication Port number of the

Robot Plotter (communication using TCP protocol). Send data (filled in an instruction) and the send button is a feature for communication tests with a plotter robot. A list of instructions is a features to fill in a series of batik motif drawings with the syntax "Turtle graphics", the image check button is a feature button to check the image results that will be plotted by the plotter robot and the process button is a feature button to send instructions to the plotter robot in a way Wifi with TCP protocol.

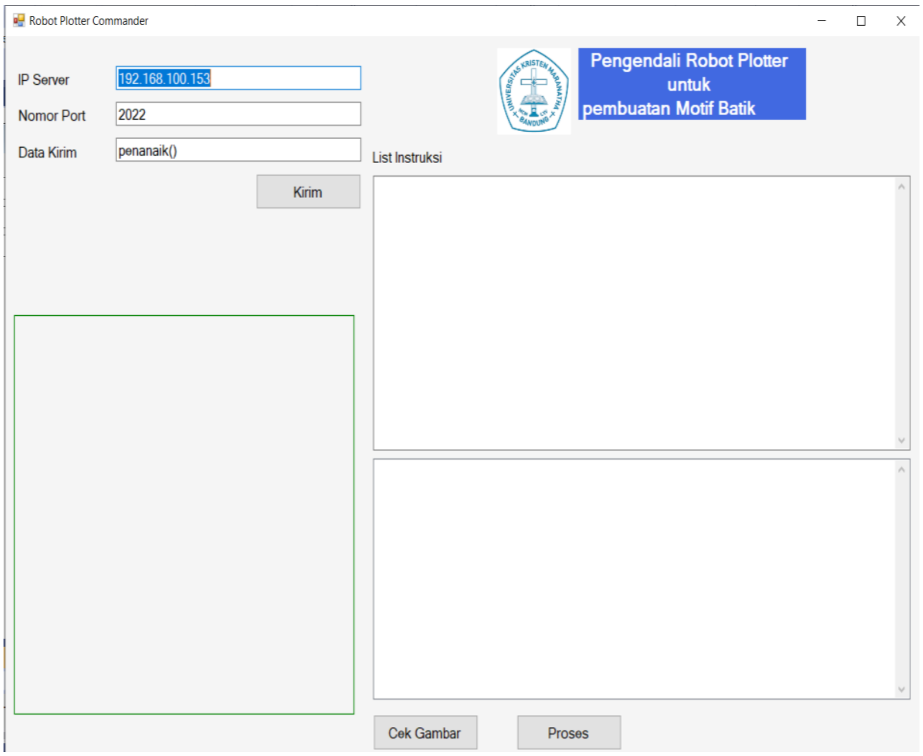


Figure 3: Display of Realized Robot Plotter Controller Interface

List of instructions given to the plotter robot to create batik motifs using the turtle graphics algorithm, the interface will translate a list of instructions like in Table 1.

Table 1: Function Turtle Graphics

penup()	Raise the pen up, sliding mode
pendown()	Lower the pen down, image mode
foward()	Foward as much as n steps
back()	Back as much as n steps
left()	Turn the direction to the left as far as SDT degrees (0-360 degrees)
right()	Turn the direction to the right as far as SDT degrees (0-360 degrees)
circle()	A circle image with the radius n
square(length, width)	Picture box length x width
Polygon(x,n)	Image of polygon x angle, with long n
Repeat[k;inst1;inst2;…;instn]	Repeat the order of inst1 process, inst2, .., instn as much as K times

The software use flow that is designed can be seen in Figure 4: Flowchart Subroutine Process and Check Image can be seen in Figure 5 and Figure 6.

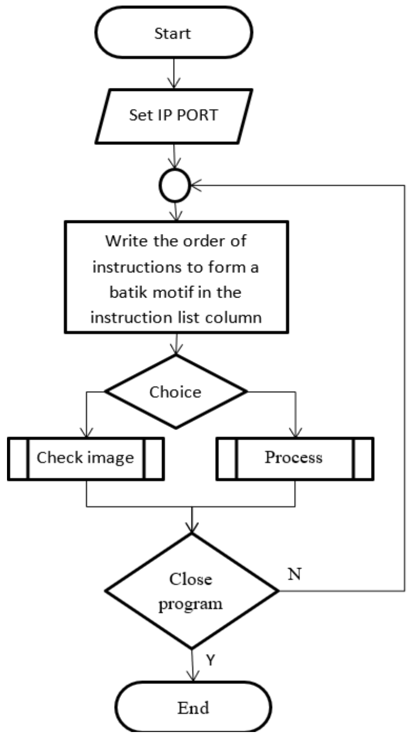


Figure 4: Flowchart Robot Plotter Controlling Software

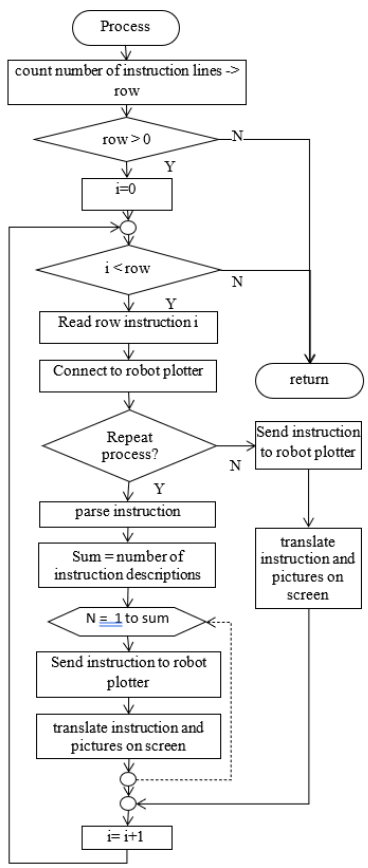


Figure 5: Flowchart Sub-Routine Process

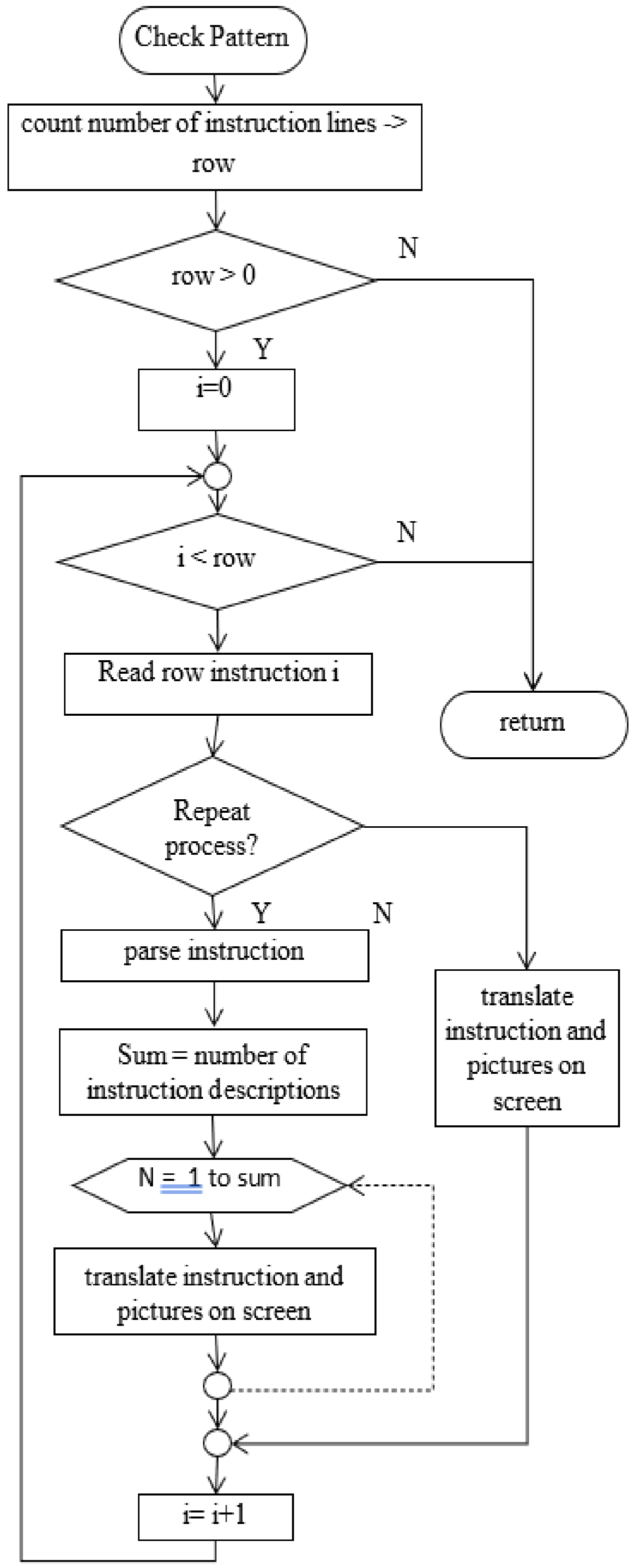


Figure 6: Flowchart Sub-Routine Check Motif

Realized hardware can be seen in Figure 7.

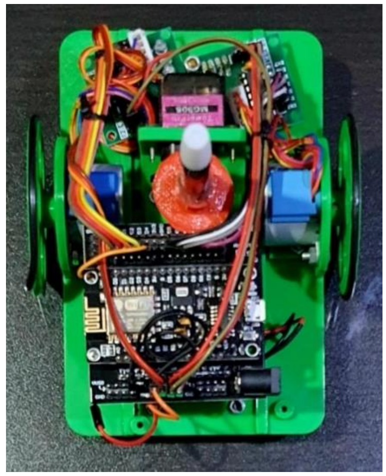


Figure 7: Realized Robot Plotter Hardware

Robot plotter software design flow diagram on Node MCU (ESP8266-12) can be seen in Figure 8.

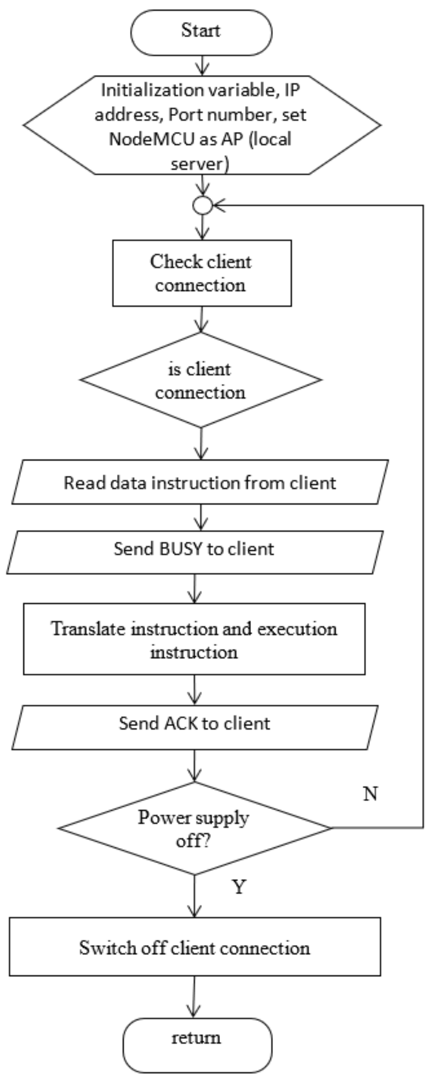
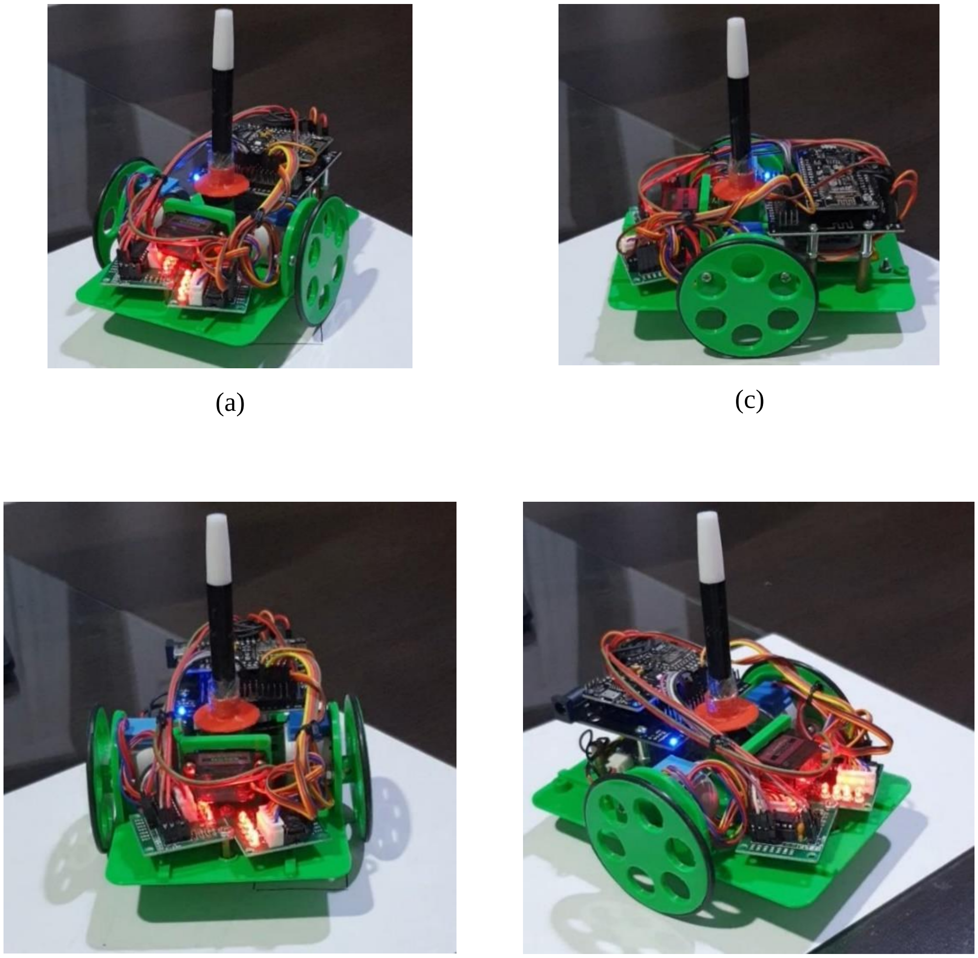


Figure 8: Robot Plotter Flow Diagram on Node MCU



(a) (c)

(b) (d)

Figure 9: (a-d) Robot Plotter Mapping Box Image

The results of making the basic batik motifs can be seen in Figure 10 (a) Triangle, (b) Longitude, (c) stars (d) batik aksara lontara Pa, and (e) batik aksara lontara Na.

Each side of the pattern is translated in the form of movement instructions from the robot plotter which is set via the turtle graphics command. The triangular batik basic pattern is entered into plotter system design by typing the turtle graphics command as follows:

```
Start()
Maju(10)    -> forward(10)
Penaturun() -> pendown()
Maju(50)    -> forward(50)
Kiri(120)   -> left(120)
Maju(50)    -> forward(50)
Kiri(120)   -> left(120)
Maju(50)    -> forward(50)
Kiri(120)   -> left(120)
Penanaik()  -> penup()
Stop()
```

The rectangular batik basic pattern is entered into plotter system design by typing the turtle graphics command as follows:

Start()
Maju(10) -> forward(10)
Penaturun() -> pendown()
Ulang[4,maju(50), kanan(90)] -> Repeat[4, forward(50), right(90)]
Penanaik() -> penup()
Stop()

The star batik basic pattern is entered into plotter system design by typing the turtle graphics command as follows:

Start()
Maju(10) -> forward(10)
Penaturun() -> pendown()
Ulang[5,maju(80), kiri(144)] -> Repeat[5, forward(80), left(144)]
Penanaik() -> penup()
Stop()

The implications for the potential use in the field of batik production are that pattern can be made in various shapes, pattern can also be enlarged or reduced (scaling), pattern can be rotated, skewed, duplicated, combined, so that pattern variations can be easier. Saving pattern by storing program instructions can minimize memory storage on computer.

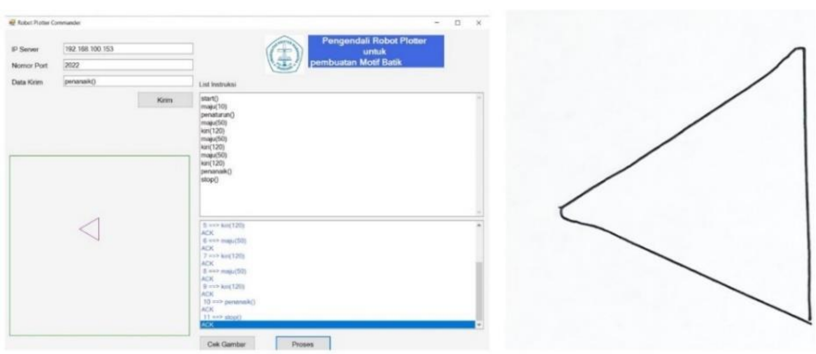


Figure 10 (a): The Appearance of a Triangle Image on the Interface (left) and the Results of the Robot Image on the Paper (right)

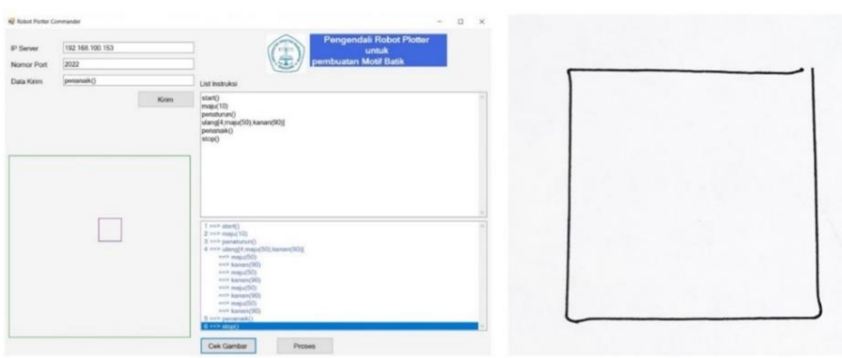


Figure 10 (b): Appearance of Box Drawings on the Interface (left) and the Results of the Robot Image on the Paper (right)

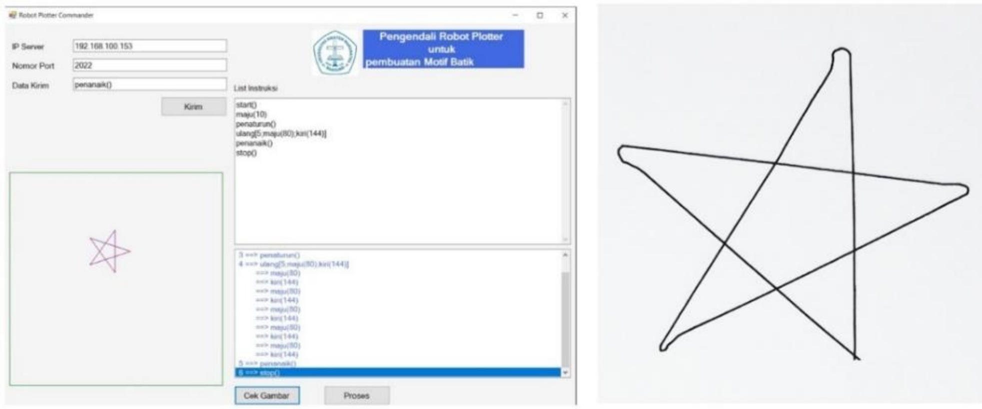


Figure 10(c): The Appearance of the Star Image on the Interface (left) and the Results of the Robot Image on the Paper (right)

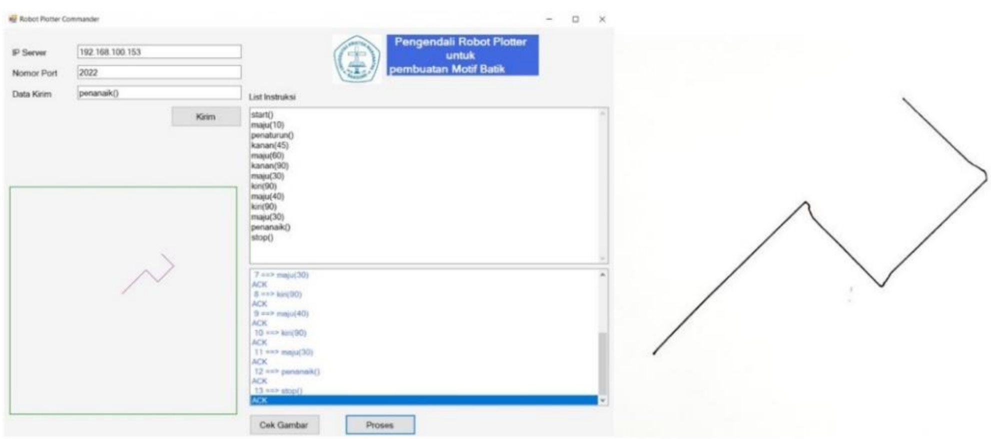


Figure 10(d): The Appearance of the Batik Aksara Lontara Pa on the Interface (left) and the Results of the Robot Image on the Paper (right)

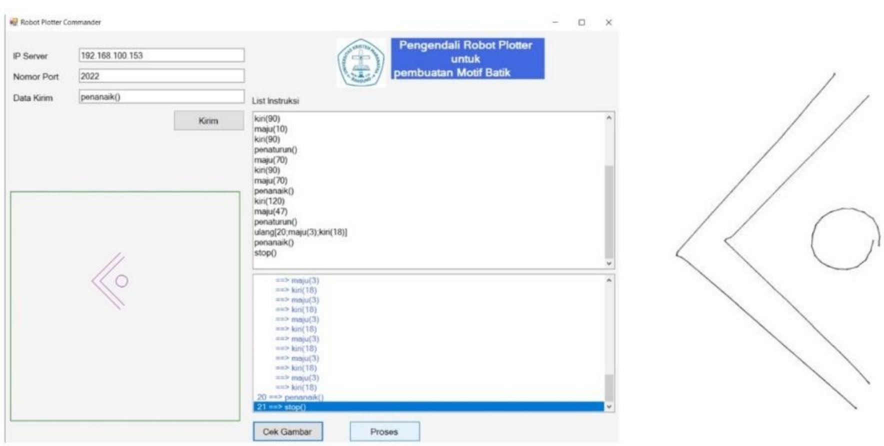


Figure 10(e): The Appearance of the Batik Aksara Lontara Na on the Interface (left) and the Results of the Robot Image on the Paper (right)

6 Discussion

The interface for connecting users and plotter robots has been successfully made to make batik motifs. Variable initialization, IP address, port number, and set Node MCU as AP (Local Server) has been successfully carried out, and the robot plotter can be controlled by users through the interface. Program listings that are entered in the "List instruction" menu window and processed can be translated into commands to move the plotter robot to make motif images. The direction and magnitude of the robot plotter motion are following the program listing written in the window menu, only the rolling of the robot and the robot mechanics is still not good so when it rotates there is excess. But the interface that was made had worked well.

The main factors that can cause errors in the plotting process for the plotter robot are the less precise wheel rotation, and when the experiment the surface area is uneven. Low production costs can be achieved by using electronic components that are commonly sold in the market, produced in large quantities, the controller system is designed on one PCB, So SMD components are used for small sizes. These features can facilitate practical applications in everyday life, for example designers draw pattern according to the needs of the batik industry or the fashion industry, applications can be used in education to train students' logical thinking.

Integration of electronic components and machines in the mechatronic process using stepper motors to control the rotation of the wheels contributes to accuracy. The efficiency of the robot plotter is obtained because the voltage supply is given only when the stepper motor is working, thereby saving the use of a voltage supply.

The programming process contributes to errors commonly encountered in the use of plotter robot. To overcome this problem, a stepper motor rotation calibration can be performed against wheel rotation and wheel size. This could increase the precision of the plotter robot movement.

7 Conclusion

The user gives instructions through a computer wirelessly through WiFi with TCP protocol (in port 2022) to move the plotter as far as and the direction specified to a certain position, the instructions are received by Node mcu ESP8266-12 and translated into instructions to the Stepper Motor Controller (ULN2003 PCB), Furthermore, the Stepper Motor Controller translates it into a step-pulse form, then the instruction /data pulse is translated into a movement on the motor stepper (28byj-48) to the position of the x-axis, the specified y-axis, while the rise / decrease of the pen on the plotter robot is controlled Through servo motorbike SG90S. A robot plotter can be used on two joints along the x and y axes. The plotter robot here is given order through a program using the Turtle Graphics algorithm to make batik motifs. Batik Motives that are tried here are the basic motifs of batik namely triangles, boxes, and stars.

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