



Designing a wireless robot plotter as a supporting tool for understanding logical thinking

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ABSTRACT

OSTR stands for Open Source Turtle Robot is a turtle robot whose hardware and software are open source and published by MakersBox located in Adair Village, OR, United States of America. In this study OSTR will be developed into an Wireless Robot Plotter that can draw and write and is equipped with computer software to support the needs of the learning process in understanding logical thinking for students. In this study, a wireless Robot Plotter design has been successfully designed to support students' understanding of logical thinking. A logical thought in the form of syntactic logic steps "turtle graphics" is inserted into the application interface (created in visual basic language), then the logic steps are translated in the form of an image that can be viewed on the monitor screen and sent wirelessly to the Robot Plotter (using nodeMCU ESP8266-12 as the processor) to be drawn by the Robot Plotter. From the tests, the realized wireless Robot Plotter successfully drew according to the logic steps instructed through the created interface application. The research urgency is to train logical thinking by designing a robot plotter so that abilities and skills are sharpened and the plotter robot used to draw basic batik motifs can be utilized by the creative industry.

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1. INTRODUCTION

In this era of "Merdeka Belajar", both educators and students need greater effort in understanding what they are learning, creativity is needed in the learning process, especially in studying scientific science (STEM = Science, Technology, Engineering and Mathematics). One of the tools that can help facilitate the understanding of the material studied in this teaching-learning process can use robot technology. For students to be able to understand logical thinking about directions and angles (or learn trigonometry) more easily, it can be helped by visualizing the movement of a robot that can go forward, backward, turn left - right according to the direction of the intended angle by drawing a line mark through which it passes, so that the direction and angle appear. For this purpose, a robot plotter can be used. In addition, the robot plotter can also be used to help draw as desired.

Research conducted by Ni Nyoman Sriningsih (Sriningsih et al., 2018) is a study of the influence of science on children's logical thinking skills, and the results show that education using science has a considerable effect on the success of children's logical thinking skills, which initially when using conventional students' average score is 59.8, using science the average score is 74.69. Robotics is a combination of a number of engineering fields including mechanical engineering, electrical engineering and computer science.

Whereas Turtle Robot started from William Walter's robotics work in the 1940s investigating complex behavior in simple systems. Turtle Robots generally move slowly with tight turning angles and distances and can be tracked by a shape design that shows the movement of the Turtle over time. A number of programming languages have integrated "Turtle Graphics". Turtle Graphics can also be used to study advanced topics such as L-systems or affine geometry (MakersBox, 2023).

Meanwhile, in the world of robotics, there is a plotter robot (Shivakumar et al., 2014) which is basically an articulated robot arm with selective compliance (SCARA). In general, SCARA is an autonomous robotic arm with three Degrees of Freedom (DOF) and two joints that are flexible along the XY axis but rigid along the Z axis. The research was conducted by making a 2D Plotter Robot using an ATMEGA 8 microcontroller with an Arduino platform, 2 servo motors to move in the direction of the axis and a servo to raise/lower the pen.

Next is research by (Aditi et al., 2019) who developed a robotic arm aimed at physically assisting disabled people to write. The mechanism is that the user's speech recognition system is programmed to write what is spoken. The robotic arm is programmed to write down the words that the user or individual speaks into the microphone. To perform the writing operation, a pen is attached to the robot arm.

Next is research conducted by (Megalingam et al., 2018), which is to create a low-cost drawing bot that works based on Computer Numeric Control (CNC =Computerized Numeric Control) with the aim of education and increasing students' interest in robotics. Further research that aims to help the education system make it more interesting with speech recognition techniques, based on the Arduino ATMEGA328 microcontroller to control robot arms with servo motors based on commands (input) from users was conducted by (Balathangam et al., 2017). The next research conducted by (Sindhuja et al., 2020), which is developing a robot system to write and recognize speech as input from users, aims to help people with Dysgraphia: a disorder in the ability to write, especially handwriting, and is a transcription disability, which means a writing disorder related to handwriting disorders, orthographic codes, and finger sequencing (muscle movements needed for writing).

Next is Po-Jen Cheng et al.'s work on open and distributed learning. (Cheng et al., 2021), Microbit Robotics Course with Online Group Learning System (OGS) After Robotics Course Shows Positive Increases in Proportional Thinking, Probabilistic Thinking, and Analytical Ability of Students, designed to facilitate student learning anytime, anywhere. problem. As a result, it became clear that there is a gender difference in the relationship between students' logical thinking ability and problem-solving ability. The following was proposed by (Matson et al., 2003) is a robotic he simulator to improve critical thinking skills from preschool through his sixth grade. The effects of using simulators to increase neuroplasticity and improve thinking skills can be lifelong.

Next is a study by (Veenman et al., 2022) examines whether computation and reasoning are related. They therefore examined the effect of a robotics course on logical and calculative thinking in 14-year-old Dutch schoolchildren. This study, which used a small sample size (35 students), does not show an impact of robotics courses on logical or computational thinking.

We then follow the method developed by (Mitnik et al., 2008) use robotic real environments to teach non-robot related subjects such as mathematics and physics. In

relation to its teaching potential, it has been shown than the proposed educational framework can help students to understand different physical and mathematical concepts, such as geometry and kinematics. Regarding collaboration, teamwork among students was mainly achieved based on the wireless remote interfaces, since it was using these devices that the robot was capable of distributing roles among the students, and of providing different software tools and hints about the proposed problems.

Next is research by (Eguchi, 2017) where educational robotics is rich with opportunities to integrate not only STEM but also many other disciplines, including literacy, social studies, dance, music, and art, while giving students the opportunity to find ways to work together to foster collaboration skills, express themselves using the technological tool, problem-solve, and think critically and innovatively. Educational robotics is a learning tool that enhances students' learning experience through hands-on mind-on learning. By bringing learning through making with robotics into every classroom, educators have the potential to provide all students with the opportunity to learn the skills and knowledge that they need to become effective members of the workforce and future innovators and creators.

Research by (Fitria & Malik, 2022) mentions that for analyzing a situation and coming up with a reasonable solution using Logical thinking. It is crucial because it can help a person reason through crucial decisions, solve problems, generate creative ideas, and set goals to be achieved, all of which are needed to develop self-competence. This research shown that students faced difficulties in developing logical thinking ability are in determining alternatives for the problems given.

According to a study by (Tripathi et al., 2018), the XY Plotter is a type of robot that boasts a speedy and efficient method of creating large-scale drawings. This particular robot operates using a vector graphic device and an Arduino UNO microcontroller, which enables it to draw or sketch images from computer input onto a drawing board or sheet of paper. The process involves a polargraph-based Arduino program, which ensures precise diagramming. Additionally, the robot has two-axis control (X and Y) and employs a unique mechanism to raise and lower the pen. Each axis is driven by a single servo motor, while the pen control is managed by a suspended servo motor controlled by two fixed stepper motors located at the corners of the drawing surface. Thanks to this setup, the XY Plotter is able to complete tasks quickly and efficiently.

The research conducted by (Conradty & Bogner, 2018) discovered that the definition and measurement of creativity are intricate and challenging. As such, modern learning for teenagers in STEM subjects has adopted a STEAM approach, incorporating traditional creative subjects such as Art. To evaluate individual creativity, the study utilized an 8-item questionnaire (measured on a Likert scale) that was administered to a sample of 2713 students aged between 11-19 years. The findings indicated that gender did not play a role in determining creativity scores, and younger students received higher scores than older students. Additionally, the study offered recommendations for implementing STEAM lessons. The use of WiFi in infrastructure is attracting researchers and companies to the use of object location. Precise location accuracy reduces noise. The results of estimating errors and reducing calculation time are the focus of this study (Thewan et al., 2019)

Improving the ability to solve problems with logical thinking skills and understanding concepts is the focus of research(Shafina et al., 2020). This can be measured by providing pre and post tests to answer a number of questions. The use of the CPS learning model is used as a tool in measuring logical thinking skills and understanding concepts. It is important for the student's learning stage and mental development process.

Research conducted by (Rossi et al., 2023) on trajectory tracking control systems on multi-robots has been carried out. The purpose of the study here is to obtain

coordinates on trajectory tracking. Control is done by communication via wireless to calculate the speed of movement of the robot. Tests are carried out by numerical simulation. Control results are measured performance online. Another study conducted by (Lamprou et al., 2020) about two fast robots to move objects via wireless communication. The focus of the study is the regulation of the speed of each robot moving straight, the optimal transfer strategy and execution time are taken into account as well.

(Chalmers & Nason, 2017) in his research using robots in schools in his learning curriculum to improve students' thinking. The conceptual approach, design, and implementation of the robot curriculum will make students learn about science, technology, engineering, and mathematics (STEM). Robot learning is rich in context so that students can gain knowledge and understanding about STEM. Materially and socially students can obtain when studying, designing and implementing robots through STEM knowledge.

Based on previous research in this study, wireless communication was used to move the plotter robot. The difference with previous research is that this design is to support understanding of learning about STEM to draw basic batik motifs by utilizing the turtle graphics algorithm. In this design, students learn about electronic components, turtle graphics algorithms, STEM, programming, and batik design. The advantages of research here spur someone to learn applicable problems and better learn logic.

2. RESEARCH METHOD

In this research, a wireless robot plotter hardware is designed and made (the purpose is made wireless so as not to be bothered by the wiring connection system between the computer and the robot) equipped with a software placed on a personal computer / laptop whose function is to write logic steps in turtle graphics syntax as a learning process in understanding logical thinking, then the logic steps are translated in the form of images that can be seen on the monitor screen and the logic steps are also sent wirelessly via WiFi with UDP protocol to the Robot Plotter (using NodeMCU ESP8266-12 as a processor) to be translated and drawn by the Robot Plotter.

2.1 OSTR (Open Source Turtle Robot)

OSTR stands for Open Source Turtle Robot is a turtle robot whose hardware and software are open source (registered with the OSHW association with number US0125) and published by MakersBox located in Adair Village, OR, United States of America and was originally designed for a 10-hour robotics workshop on STEM topics for young women initiated by the humanitarian organization chickTech.org (Olsen, 2021). The purpose of the robotics workshop was designed to be easy to build, easy to program, interesting and low cost and can be taken home and can continue to be learned.

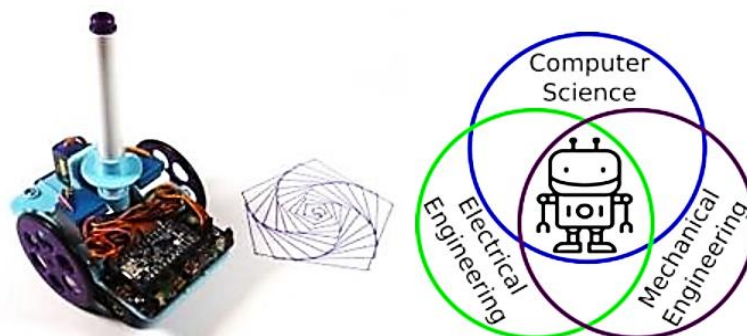


Figure 1. OSTR and intersection of various fields of science in robotics

Robotics is an interesting intersection of science from a number of engineering fields including mechanical engineering, electrical engineering, and computer science (Figure 1). Many kinds and types of robots have been created, one robot that is interesting and can be used for learning is the Turtle Robot, because it can be controlled by simple instructions such as "forward (distance)" and "left (degree)", and its visual track is instructive and entertaining. This robot shows that with a simple rule system, it can have complex behaviors. Figure 2 shows an illustration of how the visual track of a graphic turtle is formed using only a few lines of instructions in python.

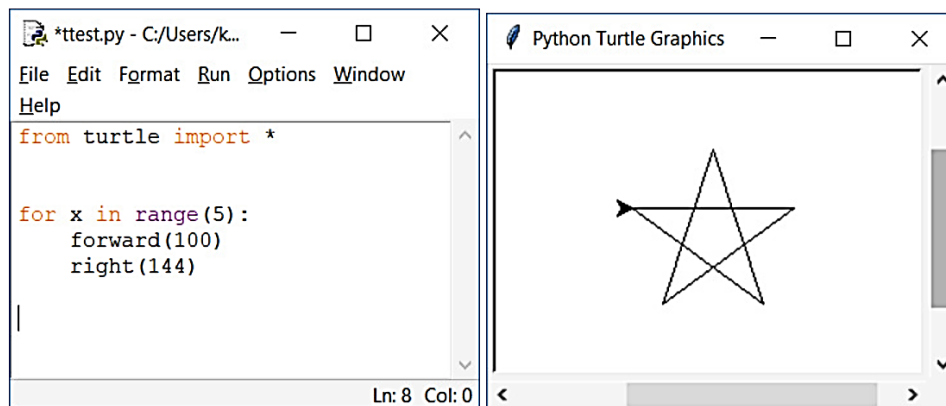


Figure 2. star visual track creation instructions on turtle graphics
Source: <https://github.com/aspro648/OSTR>

2.2 NodeMCU ESP8266-12 Microcontroller Module

NodeMCU ESP8266-12 (Make-it.ca, 2021) (Node Micro Controller Unit) is an open-source software and hardware made in the form of a low-priced System-on-a-Chip (SoC) based on ESP8266-12. The ESP8266, designed and manufactured by Espressif Systems is embedded with a Tensilica L106 32-bit micro controller unit (MCU), Wi-Fi transceiver and RAM. This device functions similarly to the Arduino UNO module and is an excellent choice for Internet of Things (IoT) projects or wireless devices. The Node MCU has a standard interface for interfacing with sensors, actuators and other boards via serial or WiFi communication. With the WiFi feature, the NodeMCU module has an advantage over the Arduino UNO, because its use can be used for wireless communication.

Figure 3 shows the position/location of the I/O terminal pins of the ESP8266-12 NodeMCU (Nerd, 2019), has 17 GPIO (General Purpose Input/Output) pins, which can be used as Input/Output are 11 pins (6 IO pins are used for flash-programming), the maximum current of each pin is 12 mA, has 1 analog input pin with 10 bit resolution (pin A0), equipped with a Wi-Fi communication module. The NodeMCU works at a voltage of 3.3V, the Input pins can be connected to switches or various sensors, for example: temperature, light, pressure, voltage, current, gas sensors and the Output pins are usually connected to indicator/control devices, for example: LED, 7 Segment, LCD Display, Relay, various types of Motors (Servo, Stepper, DC) with additional amplifier circuit.

Programming on NodeMCU can use various application programs, one of the most popular is using the Arduino IDE based on the c / c ++ language.

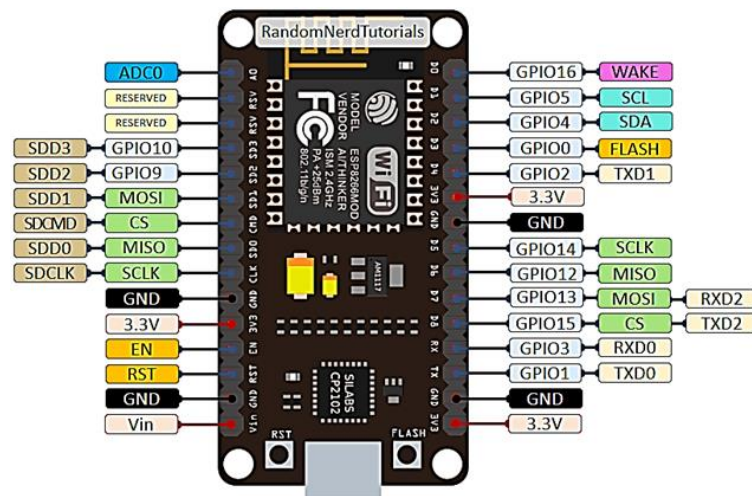


Figure 3. pin-out NodeMCU ESP8266

Source: <https://randomnerdtutorials.com/esp8266-pinout-reference-gpios/>

2.3 UDP Protocols

TCP vs UDP Communication

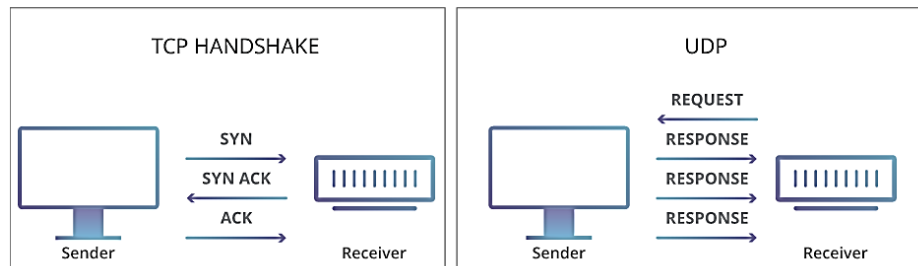


Figure 4. Differences between TCP and UDP communication protocols

Source: <https://www.cloudflare.com/img/learning/ddos/glossary/user-datagram-protocol-udp/tcp-vs-udp.svg>

Communication protocols over WiFi networks (or wire networks) can use the internet protocol (IP) and there are two types of communication in the IP scope, namely the TCP Protocol (Transmission Control Protocol) and the UDP Protocol (User Datagram Protocol) the difference can be seen in Figure 4. UDP does not require the source and destination to establish a handshaking connection before transmission occurs. In addition, there is no need for an end to end connection (Imperva, 2020). UDP avoids the overhead associated with connection, error checking, and retransmission of lost data, UDP is suitable for real-time or high-performance applications that do not require verification or correction of data. If verification is required, it can be done at the application layer. UDP has a number of advantages for small data packets and real-time applications, including: no retransmission delays, no error checking, no data verification, thus minimizing delay and increasing speed. On the other hand, with no retransmission and no error checking and data verification, UDP can have problems when transmitting packets, including: no guarantee that the packet is received properly by the receiver, no verification of the readiness of the computer receiving the message, no protection against duplicate packets.

The way UDP operates (Cloudflare, 2023): In common with other network protocols, UDP is a conventional approach to transmitting information between two computers within a network. In contrast to alternative protocols, UDP achieves this task in a straightforward manner: it transmits datagrams (units of data transfer) directly to the destination computer, without initiating a connection, specifying the sequence of these datagrams, or verifying their successful delivery. (UDP datagrams are commonly known as "packets".) UDP is swifter but less dependable than TCP, an additional widespread transportation protocol. During TCP communication, the two devices initiate a connection by performing an automated process known as a 'handshake.' The actual transmission of data packets from one computer to the other will only commence once this handshake has been completed.

2.4 Hardware Design

The design of the realized wireless Plotter Robot is in the form of a Turtle Robot and the robot block diagram can be seen in Figure 5 and the realization is shown in Figure 6:

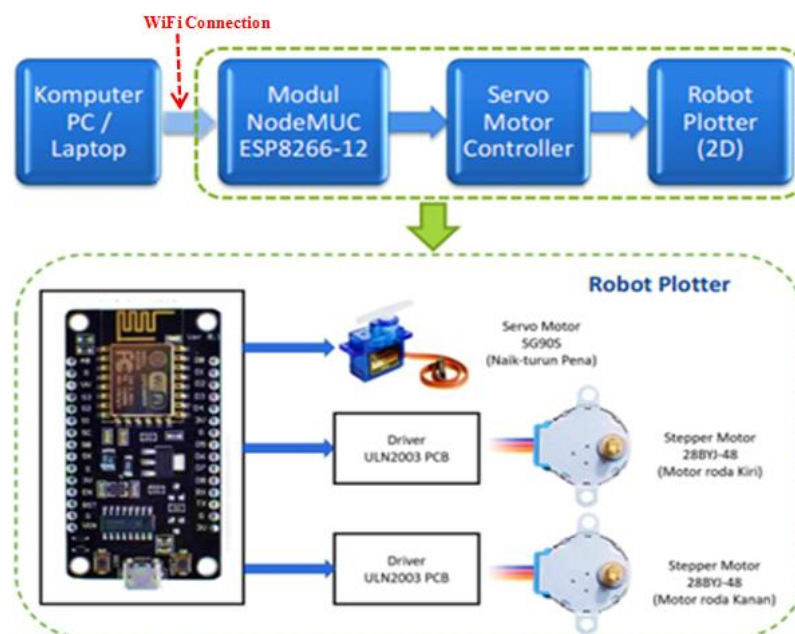


Figure 5. Block Diagram of Wireless Robot Plotter

Source: Aan Darmawan, 2022

The design of the Robot Plotter System that is done, the user (interacting) gives instructions through the computer wirelessly via WiFi with UDP protocol (on Port 8300) to move the plotter to a certain extent and direction, the instruction is received by the NodeMCU ESP8266-12 and translated into instructions to the Stepper Motor Controller ULN2003 PCB (Watson, 2017), then the Stepper Motor Controller translates it into the form of STEP pulses, then this STEP Pulse instruction / data is translated into movement on the 28BYJ-48 stepper motor (Engineers, 2019) towards the specified x-axis, y-axis position, while the up/down of the Pen on the Robot Plotter is controlled through the SG90S servo motor (Teams, 2023).

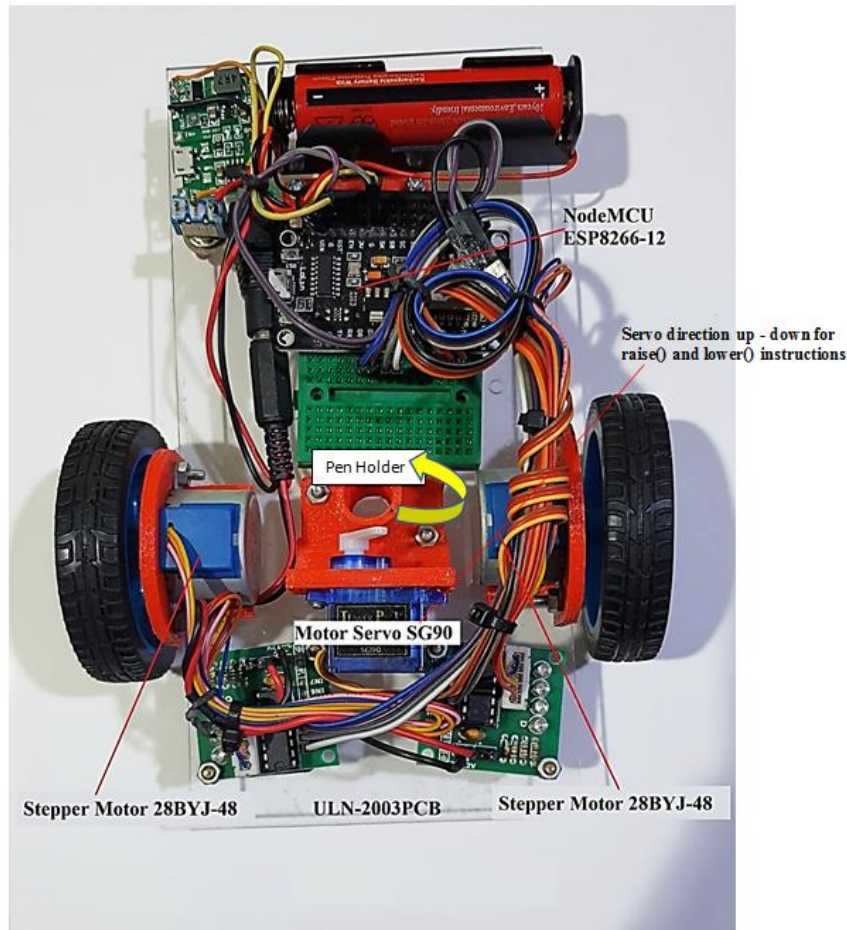


Figure 6. Photo Realization of Wireless Robot Plotter
 Source: Aan Darmawan, 2022

2.5 Software Design

The user interaction with the software to enter logic steps in the form of basic turtle graphics syntax is already in Indonesian and written in the Instruction List window; The basic turtle graphics syntax supported is `penanaik()`, `penaturun()`, `maju(jarak)`, `mundur(jarak)`, `kiri(sudut)`, `kanan(sudut)`, `kotak(tinggi, lebar)`, `poligon(nsdt,jarak)`.

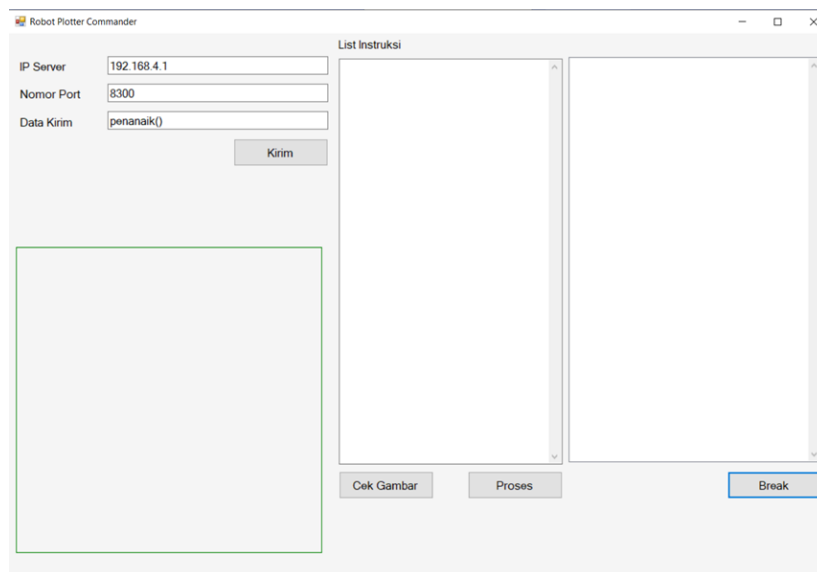


Figure 7. Plotter Robot controller App Interface

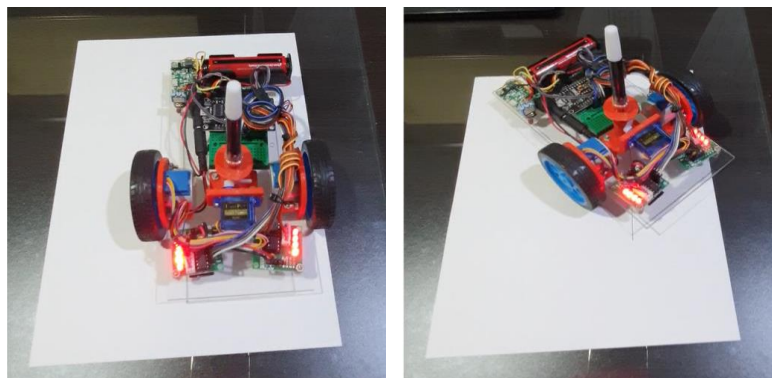
Source: Aan Darmawan, 2022

The Server IP and Port Number content boxes function for setting the IP address of the Robot Plotter and the opened communication Port Number (UDP protocol), the green box window is for visualizing the image of the plotter robot movement direction to be done (drawing if given the `penaturun()` instruction), the Process button functions the computer executes each syntax in the instruction list window and at the same time sends instructions to the robot plotter via WiFi with the UDP protocol, while the Check Image button functions like the Process button but only for checking (drawing on the monitor screen, not sending instructions to the Robot Plotter). The Break button serves to stop the process immediately, and the right window serves to monitor each work step of the robot while the process is working.

3. RESULTS AND DISCUSSIONS

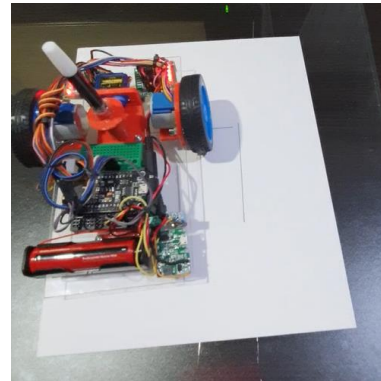
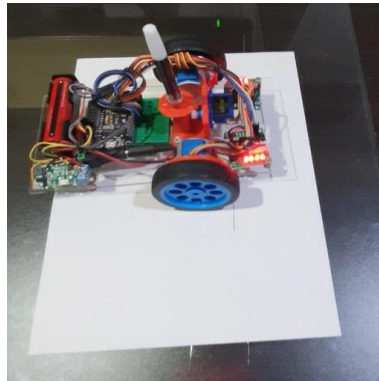
Data was collected to test the performance of the plotter robot and also to test the plotter robot to draw some simple shapes.

Testing the performance of the device made, carried out by instructing the plotter robot to move to draw a box, and the results of its movements can be seen in Figure 8.a to Figure 8.f.



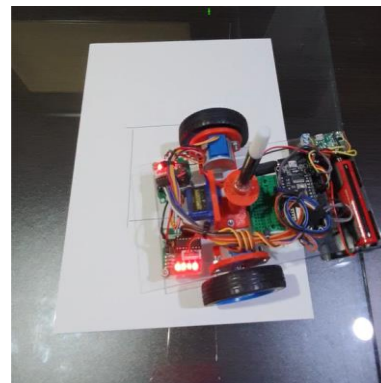
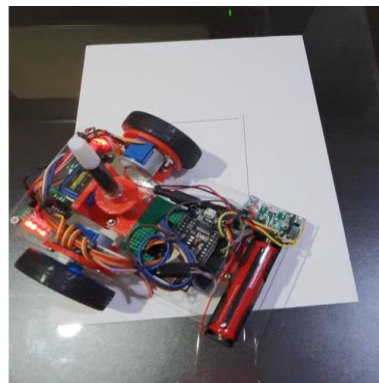
(a) The robot moves forward

(b) Robot turns left 90°



(c) The robot moves forward

(d) Robot turns left 90 ° & forward



(e) Robot turns left 90 ° & forward

(f) The robot moves forward & to the starting position

Figure 8.(a – f) Movement of the plotter robot while drawing a box
Source: Aan Darmawan, 2022

Testing the robot plotter against the instruction to draw some simple shapes was done by drawing a triangle (figure 9.a), drawing a rectangle (figure 9.b) and drawing a star (figure 9.c).

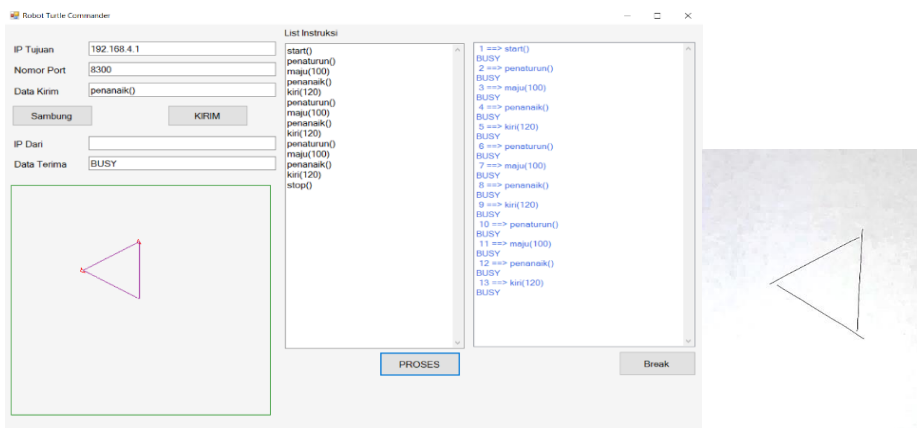


Figure 9.a View of the triangular image on the interface (left) and the resulting robot image on paper (right)

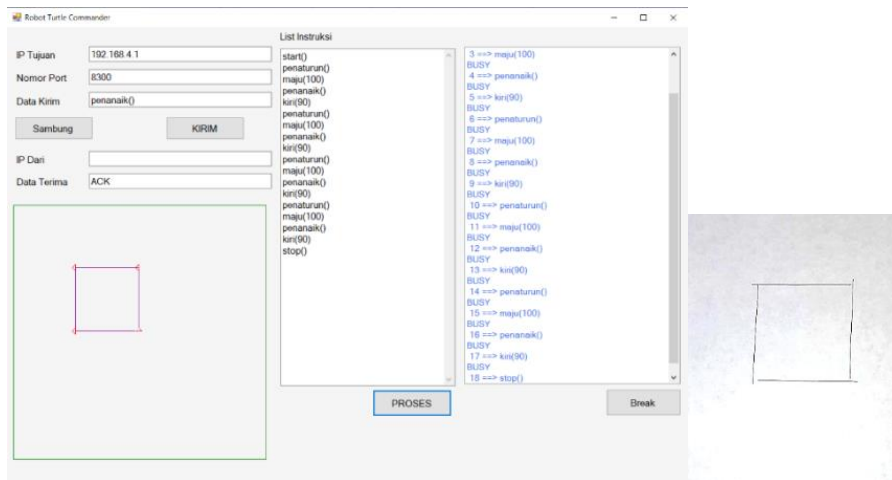


Figure 9.b View of the box image on the interface (left) and the resulting robot image on paper (right)

Source: Aan Darmawan, 2022

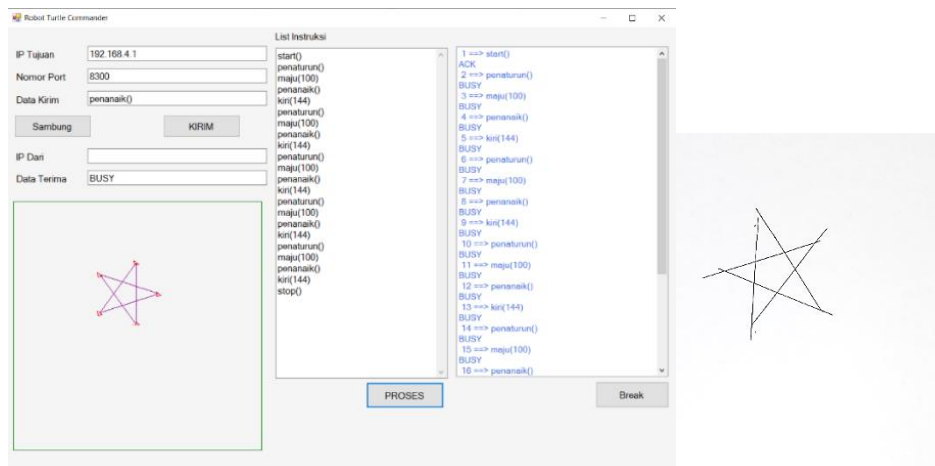


Figure 9.c View of the star image on the interface (left) and the resulting robot image on paper (right)

From the results of the above tests, the wireless Robot Plotter successfully works to move according to the logic instructions sent from the computer via WiFi network (UDP protocol).

4. CONCLUSION

The realized wireless plotter robot successfully moves according to logic instructions and is ready to be used to train logical thinking patterns through a series of “turtle graphics” syntax, but the results of the image formed are not perfect, it is necessary to make improvements and calibrate the mechanical hardware so that the image results are even better. This software can be developed by adding features such as conditional statements, loop statements and array data. The next stage can be done testing the effectiveness of this wireless plotter robot to be used in learning logical thinking methods by conducting a trial survey to many students as respondents. The limitation of the research here is the motion of the wheels related to the motor, the precision is still not good so the motifs produced when forming the star motif at the end of the line are drawn longer, and this can be used as further research in the future.

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