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Design of Semarang Denok Dance Robot Arm Movement Using STM32F103C8T6 Microcontroller

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Abstract – Research and development of human robots continues to progress in Indonesia, one of which is through the Indonesian Robot Competition (KRI) organized by the Indonesian Talent Development Agency (BPTI) at the National Development Agency (Puspresnas) under the Ministry of Education, Culture, Research and Technology in the Republic of Indonesia. This event consists of several parts, including the Indonesian Robot Dance Competition (KRSTI). This study aims to design and implement a robotic arm movement system that is able to imitate the Denok dance movements, a typical Semarang dance, using the STM32F103C8T6 microcontroller. This project integrates robotics technology with local cultural arts as an effort to preserve culture through technological innovation. The system is designed using an XL-320 servo motor to produce precise movements that resemble human movements, while the STM32F103C8T6 microcontroller is used as the main control brain. The test results show that the robotic arm successfully imitates dance movements with a high level of precision and good synchronization. This study is expected to be the first step in the development of cultural arts-based robotics and encourage new innovations in preserving local culture.

Keywords: Robotics, Denok dance, STM32F103C8T6, cultural preservation, robot technology.

I. INTRODUCTION

The word robot is taken from the Czech language (Chech), which means worker [1]. Robotics is one example of an electronics field that is currently developing rapidly [2]. Robots were created to facilitate daily human activities, ranging from robots that can help with fires, robots that can see situations and conditions through the air and robots that can carry out activities like humans [3]. Research and development of human robots continues to progress in Indonesia. The development of robotics occurs in almost every sector of life such as the military, manufacturing, industry, health and other sectors [4]. There are many initiatives to support development, one of which is through the Indonesian Robot Competition (KRI) organized by the Indonesian Talent Development Agency (BPTI) at the National Development Agency (Puspresnas) under the Ministry of Education, Culture, Research and Technology in the Republic of Indonesia. This event consists of several divisions, one of which is the Indonesian Robot Dance Competition (KRSTI) [5]. For competition in the world of robotics, every year a robot contest is held, especially in Indonesia [6]. In the Indonesian robot contest, students are required to be able to develop their abilities in the fields of mechanics, electronics, programming, strategy, research and writing skills, as well as development towards discipline, sportsmanship, teamwork, mutual respect, and other soft skills [7]. This competition is held to increase the creativity and interest of students, especially in the scope of robotics technology which is participated by various universities [8].

The Indonesian Dance Robot Contest (KRSTI) is a competition for designing and making humanoid robots accompanied by elements of art and culture of the nation that are already famous in the motherland, especially dances that are popular among the local community [9]. The KRSTI robot contest every year provides challenges with themes of Indonesian national dances [10]. The design of the KRSTI robot requires sensor parts, processes and dance movement motions in order to work properly [11]

The importance of movement in dance is an important factor in the use of robots in this field, especially when participating in KRSTI. One of the main challenges in integrating robots into dance performances is how to control the robot's performance with the precision and quality needed to display the desired artistic performance. However, to create a dance motion on a robot takes quite a long time to estimate the servo angle used, then the microcontroller processes the value to control the DC servo motor of each robot joint. If using this method, it will require repeated trial and error until the desired dance motion is found. This problem has been solved by using the CM-530 microcontroller. CM-530 is software from a robotics development company, ROBOTIS. CM-530 is designed for use on the desktop and allows you to interact and control all ROBOTIS hardware, Dynamixel, sensors, and other hardware components [12]. However, this will not last long because the availability of components used, such as microcontrollers, sensors, and servos is limited and expensive. This research was conducted to overcome the problems that arise due to the limitations of the CM-530 board to control the movement of the dance robot. This research will use the STM32F103C8T6 microcontroller as a robot controller, using the XL-320 Dynamixel servo on the body, arms, and head of the robot. The expected result of this research is to produce a robot that is more reliable in performing movements using the STM32F103C8T6 microcontroller so that it can be a guideline for the development of dance art robots at Surabaya State University and can participate in the Indonesian dance art robot contest in the coming year.

II. METHODS

Research Stages

This research uses the research and development (R&D) method. This research method is a research method used to produce certain products and test the effectiveness of the product [13]. Testing is carried out to ensure the performance of the device whether it functions properly according to the desired design. The tests that will be carried out are as follows.

a. Servo Testing

A servo motor is a servo motor with a closed feedback system where the position of the servo motor will be informed back to the control circuit in the servo motor [14]. Servo motors consist of two types, namely digital servo and analog servo. The difference between the two types of servo lies in the signal and how the signal is processed from the receiver to the servo and how the servo uses information from the receiver to move the servo according to the desired angle [15]. Servo testing is carried out to determine whether the STM32F103C8T6 microcontroller can control the servo. Testing and data collection on the servo motor are used as actuators for the Semarang Denok dance robot. Testing is done by providing input voltage to the servo motor of 7.4V and input in the form of PWM as a signal to control the angle of rotation of the motor from the STM32F103C8T6 microcontroller

b. Movement testing

Movement testing is done to determine the level of success and smoothness of the robot arm movement in performing the Semarang denok dance motion. The servo is connected in parallel to form a dance robot arm. Each end of the dance robot arm servo is installed with a servo cable that connects to the PCB. There are several motions that will be tested, namely opening prayer, denok 1, denok 2, denok 3, and closing. Testing is done by generating servo values into the Arduino IDE program with the motion that has been made.

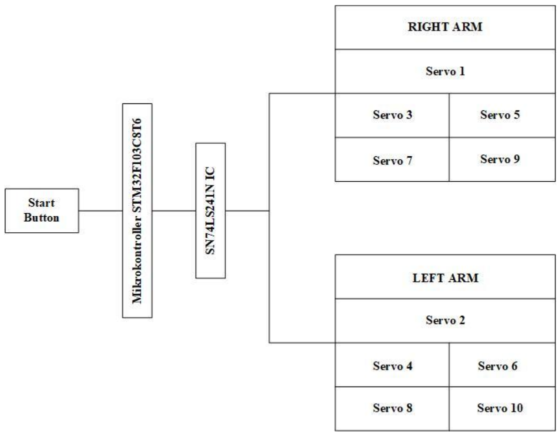


Figure 1. Research stages

The next stage after completing the mechanical, hardware and software design is implementation. The form of implementation of robotic arm movement using STM32F103C8T6 is in the form of a prototype. In the prototype research for the arm movement of the Semarang denok dance robot, it is necessary to adjust the degree of freedom represented in the prototype. Meanwhile, for the movement of the dance robot arm, it is necessary to adjust the servo value to the Arduino IDE program for the two dance robot arms in doing one movement/motion dance in Semarang.

Hardware Design

The hardware system to be created is adjusted to the specifications of the overall system to be built. Each type of hardware is studied for its specifications and technical use so that it is appropriate and relevant to each other [16]. The hardware on this robot uses the main microcontroller, namely the STM32F103C8T6, this microcontroller functions to handle the actuator in the form of the XL-320 servo. And this microcontroller is connected to the SN74LS241N IC which is used to run the XL-320 multi servo. The XL-320 servo voltage input is 7.4 Volts, therefore a mini 360 type step down is needed to adjust the 12 Volt voltage from the 3,300 Mah battery power supply to 7.4 volts for the XL-320 dynamixel servo. The servo is designed in parallel to form a human arm, therefore the PCB is equipped with a UART to upload the program to the STM32F103C8T6. The PCB is also equipped with an SMD pushbutton to run the dance robot arm program.

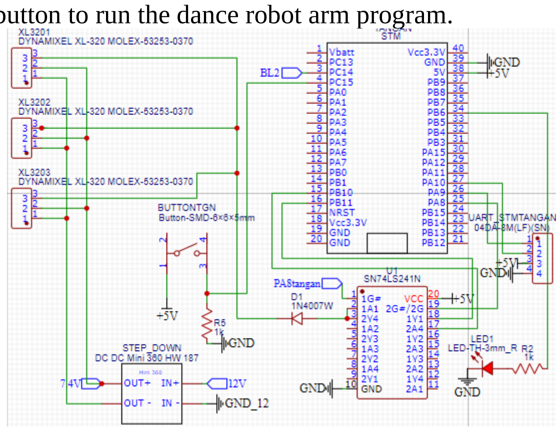


Figure 1. Hardware design block diagram

Software Design

STM32F103C8T6 controls the movements of the robot by giving commands in the form of servo positions and the desired speed of the XL-320 Dynamixel servo. The movements of the Semarang Denok dance robot are all programmed through the Arduino IDE application. This study discusses various movements, namely step 1, step 2, step 3, step 4, step 5, step 6, step 7, step 8. These movements are obtained by controlling the movements of 10 XL-320 Dynamixel servos on the robot arm.

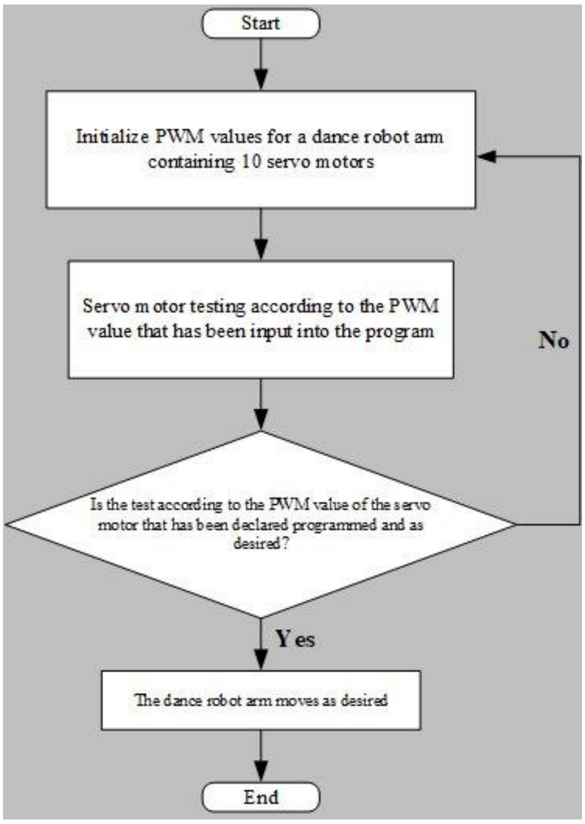


Figure 2. Software design flowchart

III. RESULT AND DISCUSSION

A. Tool Implementation

In the process of implementing the prototype of the Semarang Denok dance robot using STM32F103C8T6 can be seen in the image below. Researchers use aluminum plate material as the body, aiming to make the robot structure more sturdy and precise. The number of servo motors used in the implementation of this robot arm section is 12 Dynamixel XL-320 servo motors.

Figure 4. Robot Implementation Results Front, Left and Right

B. Servo Testing

Servo testing is carried out to determine whether the STM32F103C8T6 microcontroller can control the servo. Testing and data collection on the servo motor are used as actuators for the Semarang Denok dance robot. Testing is carried out by providing an input voltage to the servo motor of 7.4V and input in the form of PWM as a signal to control the motor rotation angle from the STM32F103C8T6 microcontroller so that it can determine the angle that corresponds to the PWM value.

In the test, the PWM value is input, each of which represents a different PWM value with a signal period set at 1 ms. Based on this setting, the Dynamixel XL-320 servo must be able to adjust its angle according to the given pulse width. The test results obtained are as follows.

Table 1. Dynamixel XL-320 Servo Motor Test Data

PWM value (µs)	Angle Reached (°)
85	25
171	50
256	75
341	100
427	125
512	150
597	175
683	200
768	225
853	250
939	275
1024	300

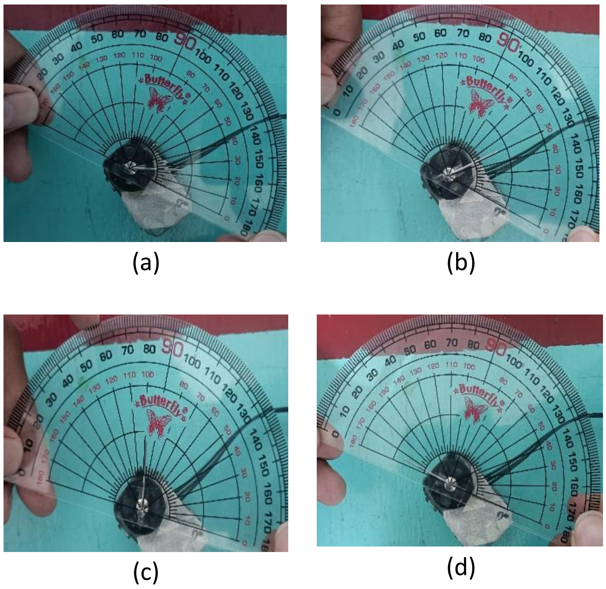


Figure 5. Servo test results
(a). 25° angle (b). 50° angle (c). Angle 100°
(d). Angle 175°

This servo responds to changes in PWM signals with excellent accuracy, and the angular position can be controlled with sufficient precision. The microcontroller STM32F103C8T6 successfully generated a stable PWM signal, which allowed accurate control of the servo position within the tested angle range.

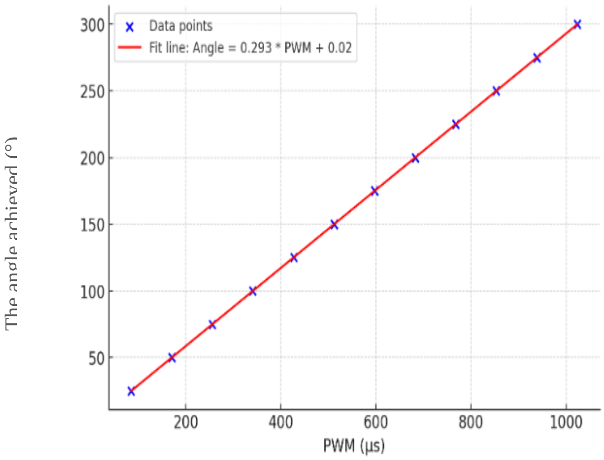


Figure 6. The graphs of servo test results

The test results show that the Dynamixel XL-320 servo provides a linear response to the given PWM value in the range of 85 µs to 1024 µs. This characteristic corresponds to the specifications of digital servos, where the position angle is controlled by the duration of the PWM pulse proportionally

C. Motion Testing

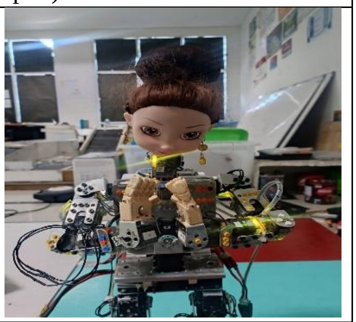
The movement test was carried out to find out what the success rate and smoothness of the robot arm movement in performing the Semarang denok dance motion. The servos are connected in parallel to form a dance robot arm. Each servo end of the dance robot arm is fitted with a servo cable that connects with the PCB. There are several step motion steps of the Semarang Denok dance that will be tested, namely step 1, step 2, step 3, step 4, step 5, step 6, step 7, step 8.

Table 2. Motion Testing Semarang Denok Dance

Step 1

(Both knees bent, hands raised to chest level, palms open)

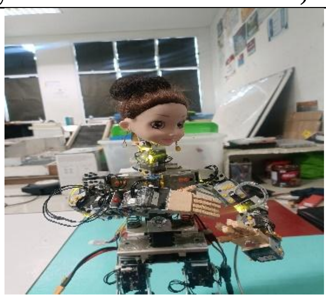
ID	PWM
1	710
2	285
3	250
4	772
5	191
6	825
7	290
8	617
9	250
10	781
11	512
12	512



Step 2

(Both robot arms extended forward, palms open, right arm straight and slightly forward above the left arm)

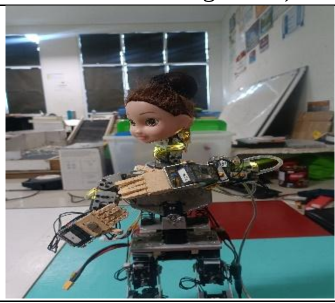
ID	PWM
1	822
2	377
3	177
4	700
5	263
6	656
7	326
8	701
9	561
10	761
11	667
12	837



Step 3

(Both robot arms extended forward, palms open, left arm straight and slightly forward above the right arm)

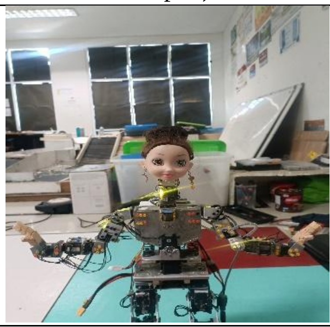
ID	PWM
1	598
2	100
3	308
4	805
5	418
6	196
7	187
8	372
9	81
10	889
11	271
12	312



Step 4

(Both arms stretched to the sides, palms facing the sides, arms symmetrical and wide open)

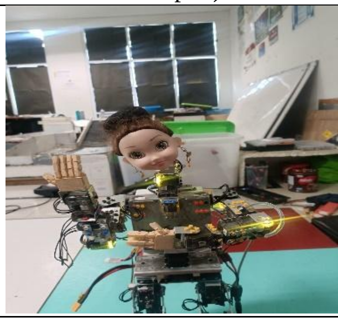
ID	PWM
1	566
2	453
3	347
4	723
5	110
6	229
7	784
8	743
9	808
10	807
11	305
12	723



Step 5

(Both arms extended to the sides, one hand clenched into a fist and the other hand wide open)

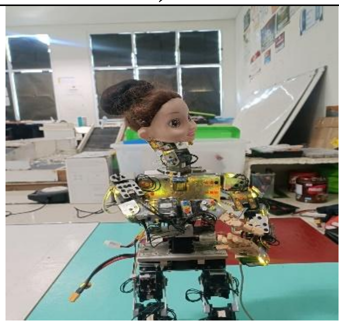
ID	PWM
1	772
2	234
3	224
4	759
5	439
6	189
7	167
8	214
9	791
10	842
11	526
12	463



Step 6

(One arm is raised upwards and the other arm is bent at the elbow. The right hand is open upwards and the left hand is open downwards)

ID	PWM
1	756
2	507
3	140
4	740
5	825
6	0
7	754
8	275
9	302
10	237
11	352
12	826



Step 7

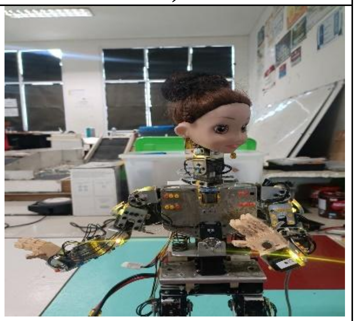
(Both arms raised upwards with elbows bent, body straight and shoulders wide open)

ID	PWM
1	0
2	1023
3	673
4	350
5	771
6	834
7	855
8	830
9	165
10	227
11	773
12	249

Step 8

(Both palms open, One arm extended to the side and the other arm bent at the elbow)

ID	PWM
1	532
2	491
3	323
4	785
5	801
6	0
7	367
8	183
9	159
10	300
11	262
12	801



In this test, the control of the robot's arm movements was carried out to simulate the dance movements of Denok Semarang, which involved various positions and dynamic movements. The microcontroller STM32F103C8T6 acts as a controller that generates a PWM signal to drive the servo motor, which is responsible for changing the angle and position of the robot's arm.

The servo motor is used to drive the robot arm according to the desired angle position. Any required angular position, such as the initial position (0°) or other dynamic movements, is precisely controlled using the PWM signal generated by the STM32F103C8T6 microcontroller. This microcontroller generates a PWM signal with high precision, which affects the position of the servo motor.

In the evaluation of the motion of the Semarang denok dance using a STM32F103C8T6 microcontroller, it can be concluded that all test tests obtained satisfactory results with a total success of 100%..

IV. CONCLUSION

This study successfully tested and analyzed two main aspects, namely servo testing and dance robot arm movements. The use of STM32F103C8T6 microcontrollers to generate PWM signals shows accurate and consistent results. This can be seen from the correspondence between the given PWM value and the angle achieved by the servo. Thetest was carried out on the robotic arm to replicate the step motion of the Denok Semarang dance, with the results showing that the robotic arm was able to imitate the movement with a good level of accuracy and synchronization.

Microcontrollers STM32F103C8T6 demonstrate adequate stability, but further development is needed to improve power efficiency, operational robustness, and motion optimization. Several factors such as the manufacturer's tolerances on servos, environmental influences, and external loads need to be taken into account in real-world applications. Further testing needs to be carried out to ensure the stability of the system under more dynamic conditions and greater loads. The development of more complex robot movements can also be done to approach the authenticity of Denok Semarang dance, thereby enriching the robot's ability to perform traditional dance arts.

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