

Review Article

Modeling and Controlling Alternate Circuits of the Educational Robot R5150 using Matlab and an Arduino Chip

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Abstract - In this article, we worked on the description of the mathematical model of the serial robotic manipulator with five degrees of freedom within the Matlab environment, where the educational laboratory model ROBOT 5150, which is the manipulator of the LAB VOLT family, which has five degrees of freedom and an effective end (pickup) was used as a case study through the kinetic study (study of forwarding and reverse movement) of this robot and its characterization within the Matlab/Simulink environment (modeling it), And alternative circuits were modeled and designed to control this arm using the Arduino mega 2560 chip and Matlab/Simulink software by linking the virtual environment in Matlab with the practical circuits. We have changed the existing controller in the design by the manufacturer and using stepper motors and servo motors, intending to make this article a reference so that students can build and develop programs and programming interfaces without restrictions imposed on drivers and maintenance programs and also use the designed program as an educational tool To gain a good experience in the field of robotic arm control and an understanding of how to program these maneuvers.

Keywords - Learning Robot 5150, 5-DOF Five Degrees of Freedom, Matlab/Simulink, Arduino mega2560.

1. Introduction

Statistics issued by the International Federation of Robotics (IFR) show that the electrical and electronic industries are the largest user of robot technologies[1], where these robots are used in assembly and sorting. Welding operations and huge companies are still engaged in large competition operations within the field of robotic maneuvers and spend huge funds to develop them. These maneuvers have become a part It is an essential part of industrial processes [2], so it was necessary to integrate robotic technologies into the scientific field, especially in the field of robot engineering and in the field of industrial automation and automatic control.

For the automation engineer to be able to engage in these circles flexibly and to be able to build operating and maintenance programs and programming interfaces for these robots and be accessible to engineers and researchers, in addition to adopting modern technologies that keep pace with the continuous and escalating development in these circles.

2. Materials and Methods

- Matlab program
- Arduino chip
- servo motor
- stepper motor

3. Research Objective

The research aims to find alternative engineering and software solutions for the educational robot 5150 away from the restrictions imposed by the manufacturer on the drivers and maintenance programs.

4. Importance of Research

The research is important for students in automation and automatic control, as modern techniques have been used to model and simulate the educational robotic arm and build the programming interface. The collation of the reverse movement depends on the final position of the effective end, where the angles of the joints are calculated by knowing the coordinates of the position.



5. Educational Robot 5150

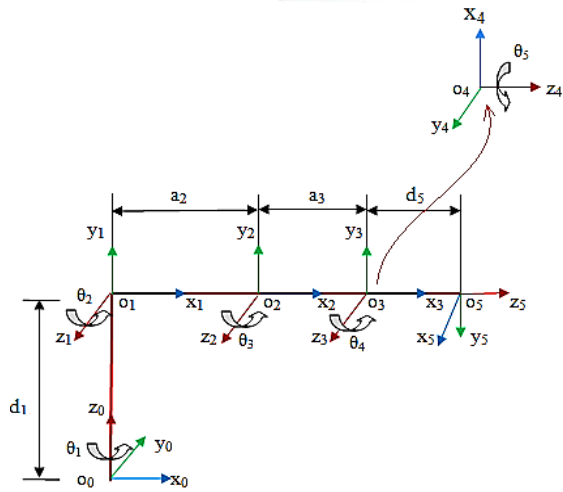
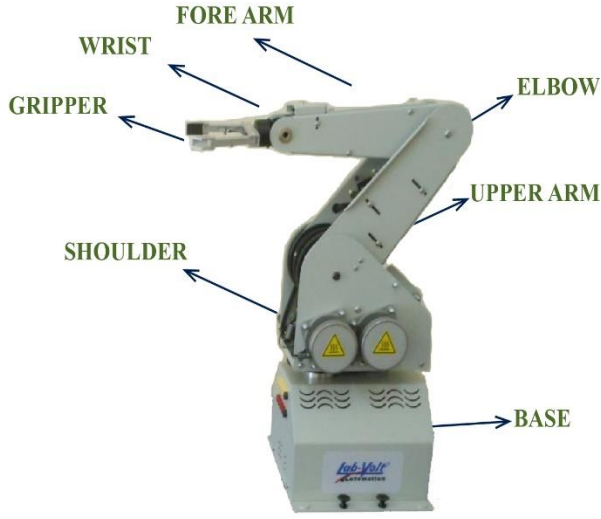


Fig. 1 The educational robot 5150 and its coordinate sentences in the Cartesian plane

The motion was analyzed using the Denavit-Harbenterg method to study the forward movement of the robotic arm, determine the coordinate system, and characterize the robot's motion with the retraction matrix and the rotational matrix for each joint called the transition matrix [5]. The transition matrix is given by:

$$T_i^{i-1} = Rot(z, \theta_i) Trans(z, d_i) Trans(x, a_i) Rot(x, \alpha_i)$$

$$\begin{bmatrix} c\theta_i & -s\theta_i & 0 & 0 \\ s\theta_i & s\theta_i & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & a_i \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & c\alpha_i & -s\alpha_i & 0 \\ 0 & s\alpha_i & c\alpha_i & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} c\theta_i & -s\theta_i c\alpha_i & s\theta_i c\alpha_i & \alpha_i c\theta_i \\ s\theta_i & c\theta_i c\alpha_i & -c\theta_i c\alpha_i & \alpha_i s\theta_i \\ 0 & s\alpha_i & c\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

Table 1. shows the D-H parameters of the 5150 educational manipulators

Frame	θ_i	d_i (cm)	a_i (cm)	α_i (degree)
1	θ_1	25.55 cm	0	90
2	θ_2	0	19.0	0
3	θ_3	0	19.0	0
4	θ_4	0cm	0	90
5	θ_5	11.5	0	0

study of the reverse movement is difficult due to the diversity of solutions achieved for the specific position.

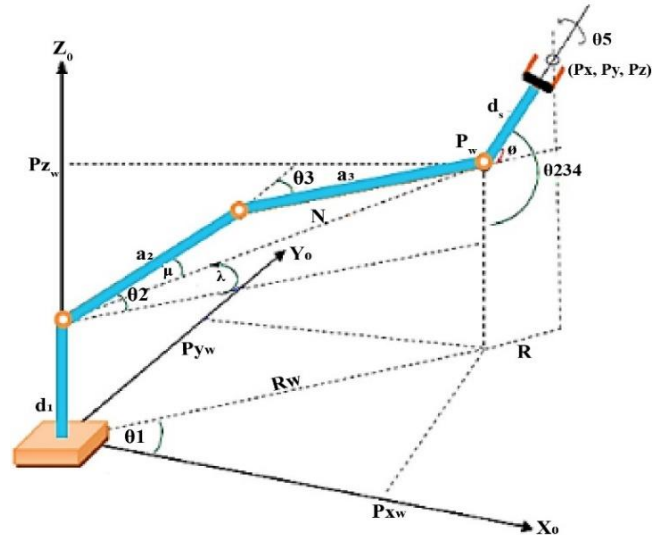


Fig. 2 The location of the robotic arm connections

$$\emptyset = \theta_2 + \theta_3 + \theta_4 \quad (3)$$

$$Pz_w = Pz + d_5 \sin \emptyset \quad (4)$$

$$R_w = \sqrt{Px^2 + Py^2} - d_5 * \cos \emptyset \quad (5)$$

$$N = \sqrt{(Pz_w - d_1)^2 + R_w^2} \quad (6)$$

$$\tan \theta_1 = \frac{py}{px} \quad (7)$$

$$\mu = \cos^{-1} \left(\frac{N^2 + a_2^2 - a_3^2}{2a_2 N} \right) \quad (8)$$

$$\lambda = \text{atan2}[(Pz_w - d_1), R_w] \quad (9)$$

$$\theta_2 = \lambda \mp \mu \quad (10)$$

$$\theta_3 = \pm \cos^{-1} \left(\frac{N^2 - a_2^2 - a_3^2}{2a_2 a_3} \right) \quad (11)$$

$$\theta_4 = \theta_{234} - \theta_2 - \theta_3 \quad (12)$$

$$\frac{n_z}{s_z} = \frac{s_5}{c_5} = \tan(\theta_5) \rightarrow \theta_5 = \tan^{-1} \left(\frac{s_5}{c_5} \right) \quad (13)$$

$\theta_5:$

$$T_5^3 = \begin{bmatrix} c_{45} & -s_5 c_4 & s_4 & d_5 s_4 \\ s_4 c_5 & -s_{45} & -c_4 & -d_5 c_4 \\ s_5 & c_5 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} n_x & s_x & a_x & P_x \\ n_y & s_y & a_y & P_y \\ n_z & s_z & a_z & P_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$n_z = s_5 \quad s_z = c_5 \quad (14)$$

6. Modeling the 5150 Robotic Arm in Matlab Environment

Depending on the D-H parameters, Table (1) models the forward movement of the serial robotic arm and finds the orientation angles in the Matlab environment, depending on the Robotic Tools, according to the following steps:

6.1. Activate the Robotic Tools

Assign values to the constants (the lengths of the connections formed for the robot L1, L2, L3, L4, L5). Enter the inferred D-H parameters shown in Table (1) using the instruction

$$L(i)=\text{Link}([\text{thi ai di a}_i]) // \text{thi: } \theta_{i-1}$$

Determine the robot's field of work by defining the field of joint angles.

Determine the type of robot (serial robot).
Robot Forward Kinematic Construction
Rob.fkine([th1 th2 th3 th4 th5])

Build the interface according to the above.

Calculate the position and direction of the moving end of the robot when moving the angle sliders.

Fig. 3 shows an interface that facilitates dealing with the 5-DOF serial robotic arm without entering into the complexities of mathematical equations, where we can calculate the coordinates of the effective end position and the steering angles by moving the angle sliders.

The reverse motion model was built based on the D-H parameters and the Robotic Tools. This model enables us to obtain the joint angles' values when entering the effective end position and direction coordinates.

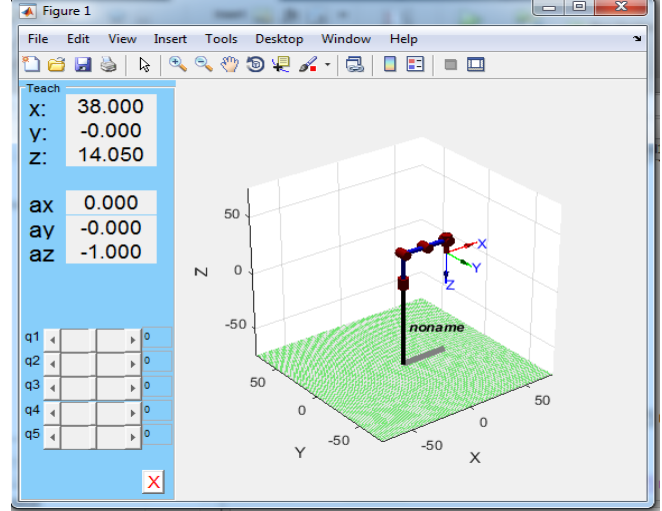


Fig. 3 Modeling the forward motion of the studied robot using D-H equations in a Matlab environment

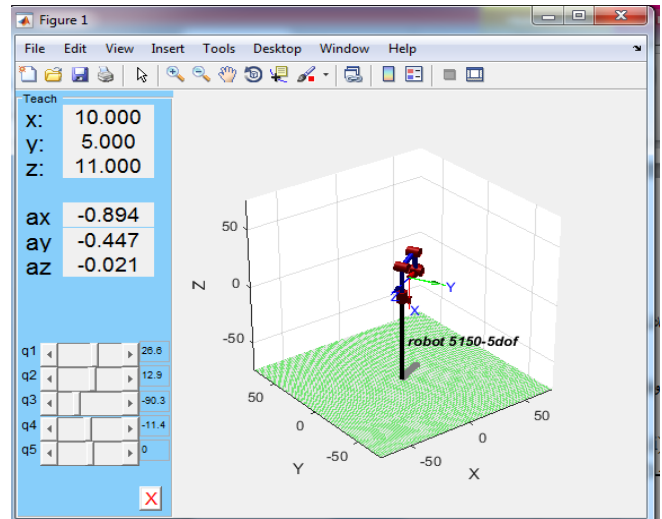


Fig. 4 Modeling the backward motion of the studied robot using D-H equations in a Matlab environment

Through the graphical programming interface built for both the reverse and forward movement of the robotic arm, we achieve ease and efficiency in handling the studied robotic arm, moving it and determining its path to any desired position in the simulation model.

7. Connection between &MATLAB Simulink ARDUINO and motor circuits

We downloaded the Arduino Uno/Nano/Mega 2560 package for programming ARDUINO Uno/Nano/Mega boards in MATLAB Simulink environment: Simulink Support Package For Arduino Hardware.

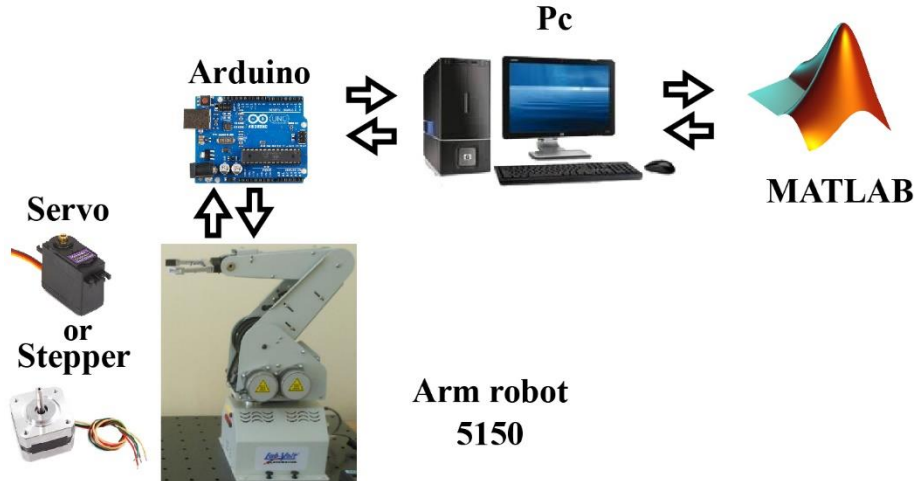


Fig. 5 Connection between MATLAB Simulink ARDUINO and motor circuits.

First: Servo dc motors. Two types of servo motors are used: servo motor continues (0-360 degree) drive for the pickup joint and servo motor stander (0-180 degree) motors for the rest of the joints; a software interface is designed in a MATLAB/Simulink environment to control the motor Servo using ARDUINO.

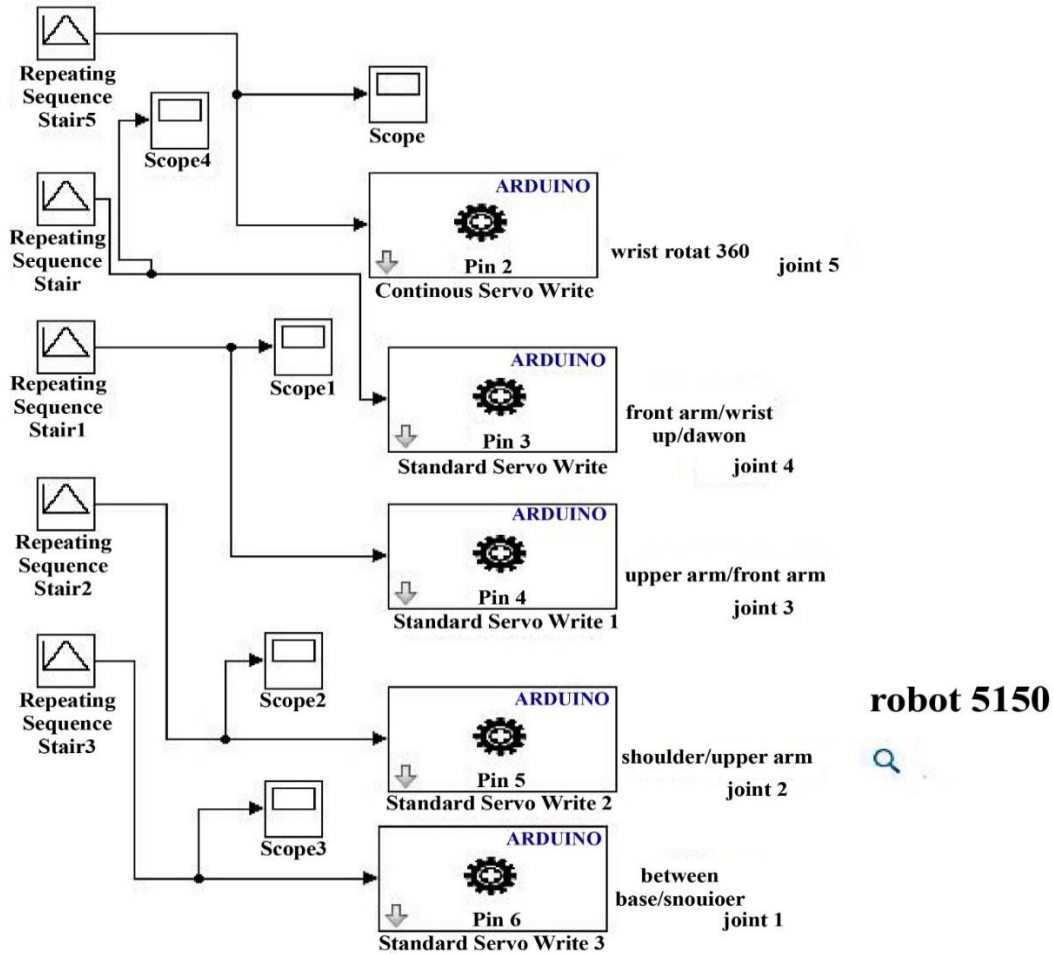


Fig. 6 MATLAB/Simulink environment - servo dc motor

Second: The stepper motors: The stepper motors need a driving circuit to be connected with the ARDUINO, where each motor is connected to the four poles of the Arduino chip.

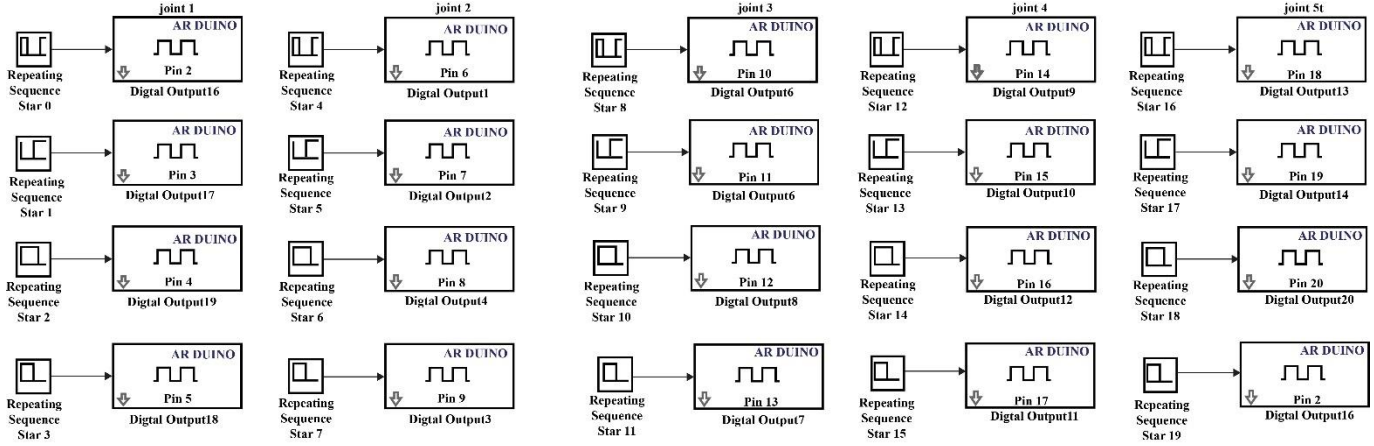


Fig. 7 MATLAB / Simulink environment - stepper motors.

8. Results and discussion

Table 2. shows the results of applying values for the applied joint angles and the effective end position of the studied robot in the simulation model

Effective end position by default	Angle values
$x = -13.4$ $y = 1.2$ $z = 62.8$	$\theta_1 = -185$ $\theta_2 = 59.7$ $\theta_3 = 51$ $\theta_4 = -180$ $\theta_5 = -135$
$x = -8$ $y = -12$ $z = -13$	$\theta_1 = -122$ $\theta_2 = -32$ $\theta_3 = -50$ $\theta_4 = 50$ $\theta_5 = 10$
$x = 38$ $y = 3$ $z = 53$	$\theta_1 = -185$ $\theta_2 = 48$ $\theta_3 = -5$ $\theta_4 = 45$ $\theta_5 = 10$

9. Discuss the Results

- This study allows researchers in the field of robotic arms to handle and control them smoothly using any microcontroller such as Arduino chips.
- Through the built-in graphical programming interface, we achieved ease and efficiency in dealing with the studied robotic arm, moving it and determining its path to any desired position in the simulation model.
- We have achieved flexibility and efficiency in work, both in terms of the software chip used and the flexibility of linking it with computer engineering programs such as Matlab and controlling the drivers connected with it.
- This study is a reference so that students can build and develop their programs without restrictions on operating and maintenance programs.

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