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Development of a programmable robotics arm using MATLAB

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Abstract
A robotic arm is a manipulator for robots that can be programmed to do tasks that a human arm can perform. As with an articulated robot, the manipulator's linkages are joined by joints that enable either rotational motion or linear displacement. A kinematic chain may be thought of as being formed by the manipulator's linkages. The robot arms may be operated autonomously or manually and are capable of performing a wide range of activities with high precision. Both stationary and wheeled versions of the robotic arm may be used in industrial and domestic settings. This study examines a robotic arm that uses accelerometers as sensors to collect data on natural arm motions to mimic those of a human arm. This method of control allows greater flexibility in controlling the robotic arm rather than using a controller where each actuator is controlled separately. The processing unit takes care of each actuator's control signal according to the inputs from an accelerometer, to replicate the movements of the human arm. Robotic arms are programmed manipulators that have a striking resemblance to a human arm in terms of design. Joints connect the various parts of the arm. Robotic arm joints, in contrast to the rotating joints seen in human arms, may be capable of varying the link length (prismatic joints). The term "end effector" refers to the device at the end of a robot's arm. It's like the robot's "hand," in a way. Arms' "work parts," or "end effectors," may be customized to perform a wide range of functions. Robotic arms may be programmed to move automatically or manually. It all relies on the purpose of the robotic arm.

Keywords: Rotational motion, translational displacement, kinematic chain, accelerometer

1. Introduction
Robotic arms are programmed manipulators that have a striking resemblance to a human arm in terms of design. Joints connect the various parts of the arm. Robotic arm joints, in contrast to the rotating joints seen in human arms, may be capable of varying the link length (prismatic joints). The term "end effector" refers to the device at the end of a robot's arm. It's like the robot's "hand," in a way. Arms' "work parts," or "end effectors," may be customized to perform a wide range of functions. Robotic arms may be programmed to move automatically or manually. Any use of a robotic arm must be justified (Mikleus, 2021) [3]. The mechanical arm of this robot is a manipulator capable of performing a wide range of activities and maybe programmed in a variety of ways.

The robot uses preprogrammed movements and points to move components, items, tools, and special gadgets. The robotic arm moves about in the real world. As directed by the controller, it moves things or tools from one location to another.

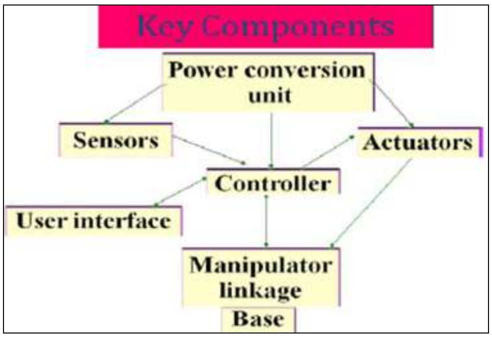
Automation is not a new concept. It started long ago with the Industrial Revolution during the 1760s. In defining automation, innovation, technology and control, are three main areas that are focused on. International Society of Automation describes automation as "the design and use of technology to monitor and manage the production of goods and services." 'Automation' Automation is a broad subject in the technological field as it covers a wide range of technological applications including robotics, communications, sensors, controls and expert systems and much more. The vision of robotics has changed over the decades. Robots were the symbol for the whole area of automation. The shift from hand production to machine production has been and continues to be of great importance in human history, this also implies that we are on the verge of another revolution based on the trends (Jackson (2019)) [4].

Robotics as defined is a technological field based on innovative ideas and mechanisms that aims to minimize human efforts to improve efficiency, accuracy and difficulty.

It is a combination of electronics, software and mechanics integrated to provide a device with automation control and automation engineering, which further focus on developing systems, that assemble; detects and move heavy or small objects. Hence, more and more businesses and factories are constantly adjusting their mode of production, whereas they are shifting from human labor to automation method that performs the same task of assembling parts to make a particular product. Given the general subject of robotics, industrial robotics is one of the most common types of robots being designed (On, 2020) [5].

2. Literature review

Automation as technology is concerned with the use of mechanical, electrical, electronic, and computer-based control systems to replace human beings with machines, not just for physical labour but also for intelligent information processing. Fixed industrial automation began in the 18th century, but in the past 15 or 20 years, it has evolved into flexible and programmable automation. This includes CNC machines, transfer and assembly lines, among other things.



Source: Hassani, 2017

Fig 1: Key components of a robot.

People are readily swayed by science fiction and so envisage a robot as a humanoid that can walk, see, hear, talk, and do the needed task. They are affected by science fiction. As a machine that can interact with and change its surroundings in response to its environment, the scientific interpretation of science fiction's robots assumes a similar definition. Therefore, defining what makes a robot is vital. A robot may be defined in a variety of ways from a variety of sources (Poole, 2019)

3. Methodology

MATLAB will be used to program the robotic arm simulator for this study. We'll choose with MATLAB because of its built-in graphical user interface (GUI) and ability to handle matrix algebra well. To begin, the application prompts the user to save the a.mat file with the necessary settings for building the robot. Creating a robot from parameters in the a.mat file is only possible if the user confirms their want to do so in the pop-up window. It then goes through the process of obtaining the user's D-H settings if the user responds with "no".

The program builds a robot simulator with all of the user interface components that are needed after it has all of the relevant parameters. The robotic arm's design and construction process is based on the operational characteristics and features of microcontrollers, stepper motors, electrical circuit diagrams, and most crucially, the programming of microcontrollers and stepper motors.

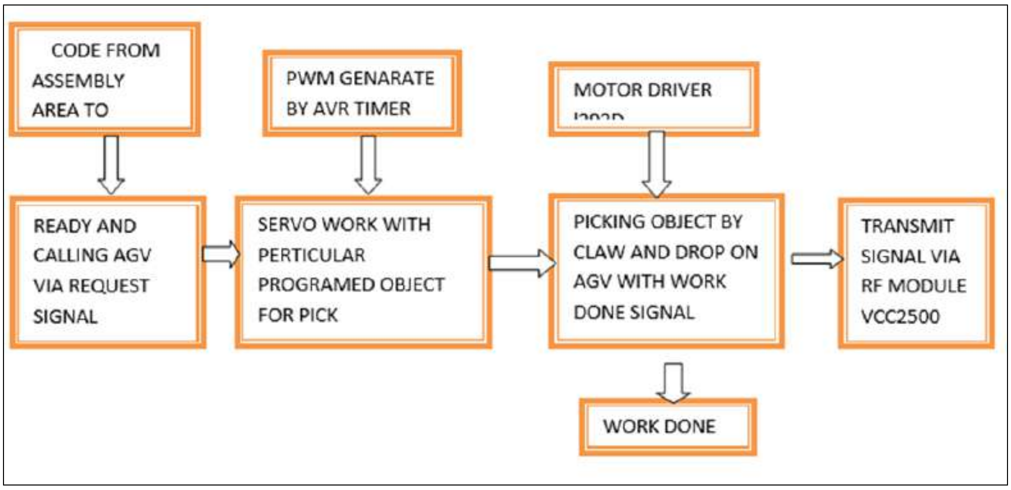


Fig 2: Block Diagram for Robotic Arm

When the signal comes to the robotic arm, it will be activated and then it searches for the code object in a storage area when it gets confirmation of availability thus it calls AGV to collect and dispatch that object to its destination of call at the instant of getting a signal inbuilt program in AVR controller activate and check the signal status incoming signal on USART terminal via RF module thus programmed AVR drive the servos with fix degree which have been placed in programming for particular objects, end effecter as a claw made up of dc geared motor and spar gear assembly with AVR via L293D motor driver h-bridge IC collect the object lift and drop on AGV and its come back its original position which is mention in its program.

3.1 The arm matrix
Next, we calculate the arm matrix for the robot

$$T_{base}^{tool} = T_0^1 T_1^2 T_2^3 T_3^4$$ Equation (1)

Table 1: Kinematic parameters

$Axis$	θ	d	a	α	$Home$
1	q_1	d_1	a_1	π	0
2	q_2	0	a_2	0	0
3	0	q_3	0	0	100
4	q_4	d_4	0	0	$\frac{\pi}{2}$

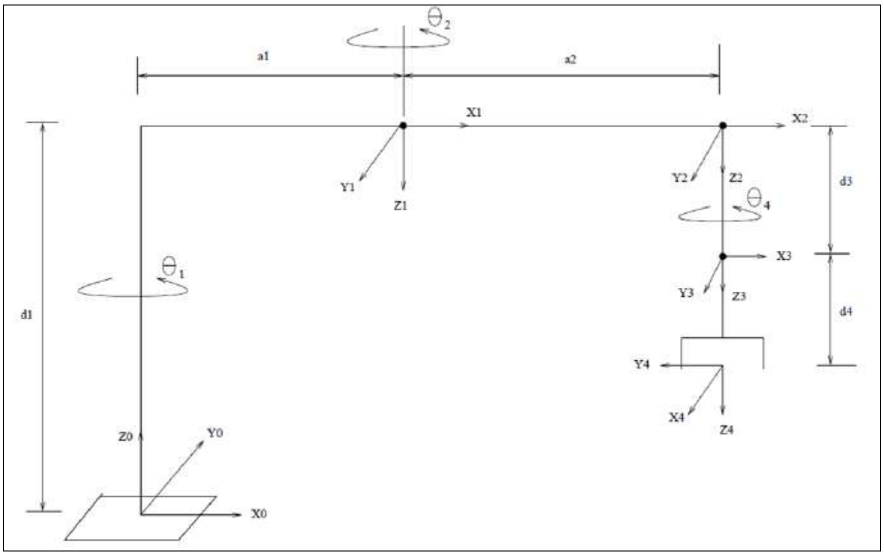


Fig 3: The link coordinate diagram

$$T_0^1 = \begin{bmatrix} C_1 & S_1 & 0 & a_1C_1 \\ S_1 & -C_1 & 0 & a_1S_1 \\ 0 & 0 & -1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Equation (2)

$$T_1^2 = \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Equation (3)

$$T_2^3 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & q_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Equation (4)

$$T_3^4 = \begin{bmatrix} C_4 & -S_4 & 0 & 0 \\ S_4 & C_4 & 0 & 0 \\ 0 & 0 & 2 & d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Equation (5)

After multiplication and simplification using trigonometric identities, we get the following arm matrix

$$T_{base}^{tool} = \begin{bmatrix} C_{1-2-4} & S_{1-2-4} & 0 & a_1C_1 + a_2C_{1-2} \\ S_{1-2-4} & -C_{1-2-4} & 0 & a_1S_1 + a_2S_{1-2} \\ 0 & 0 & -1 & d_1 - q_3 - d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$ Equation (6)

3.2 Software Design
Achieving the desired result is the only focus of the program's design. The project consists of three software modules:

1. Software development for ATmega32: A serial connection is used to communicate data from accelerometers to a computer by converting the real-time analogue signal into digital signals.
2. Software development for the Computer (Processing Unit): For servo control, the ATmega32 sends data through a serial connection. The ATmega640 receives the data, smooths it out, and then calculates the necessary timer register contents values.
3. Software development for ATmega640: To accept data from the computer and store them in their appropriate timer registers, and then create a PWM signal for servo motor actuation.

According to Fig. 4, every block receives its intermediate work/input.

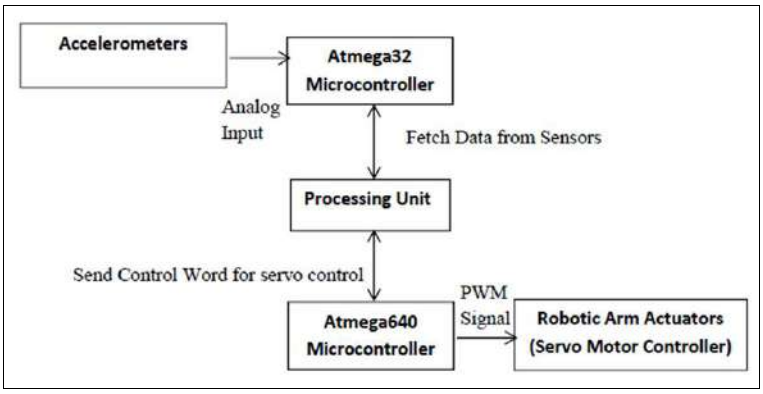


Fig 4: intermediate work/input

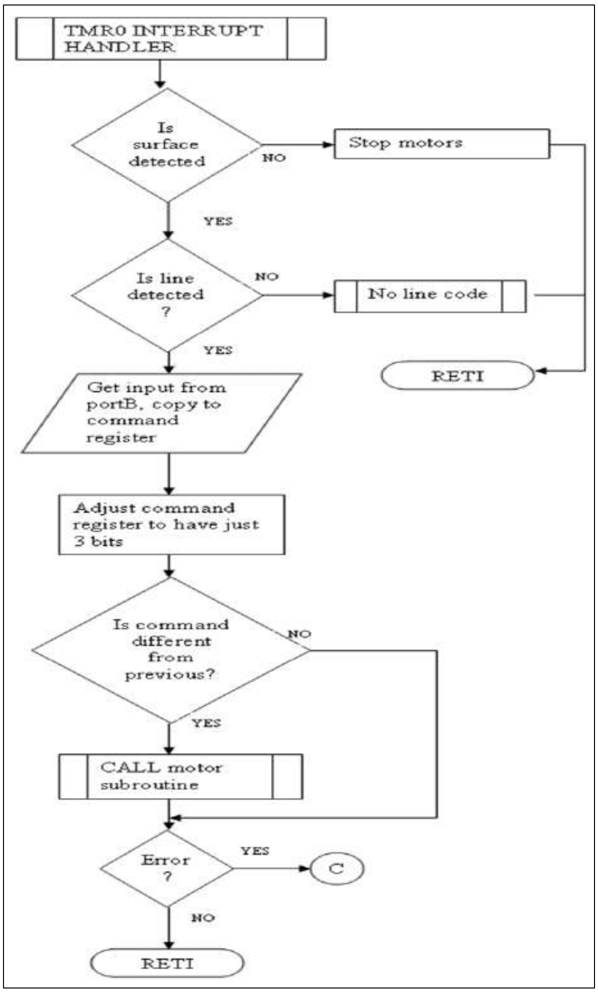


Fig 5: Flow chart of working procedure chart

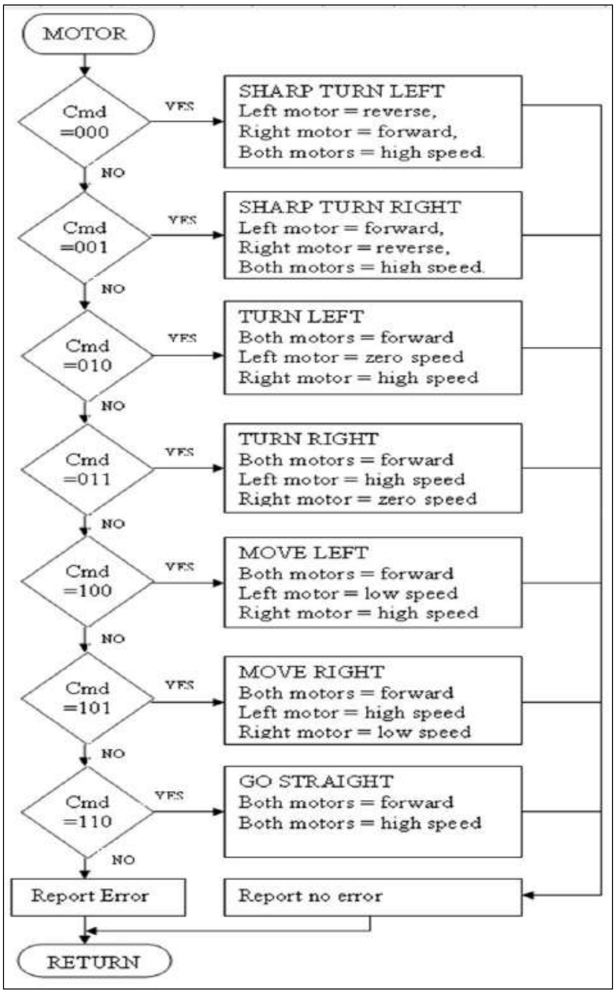


Fig 6: Operation Process for Arm Robot

4. Results and Discussion

Experimental optimizations were carried out in (1) DOF and economic optimization, (2) PPW comparison with similar industrial robotic arms, (3) system reaction speed (to ensure sufficient accuracy to pass the determined trajectories in minimum time), (4) the accuracy and repeatability of system (based on the intended function and component parameters), (5) the designed harvesting methodology evaluation, and (6) the workspace (to ensure the system meets all needs).

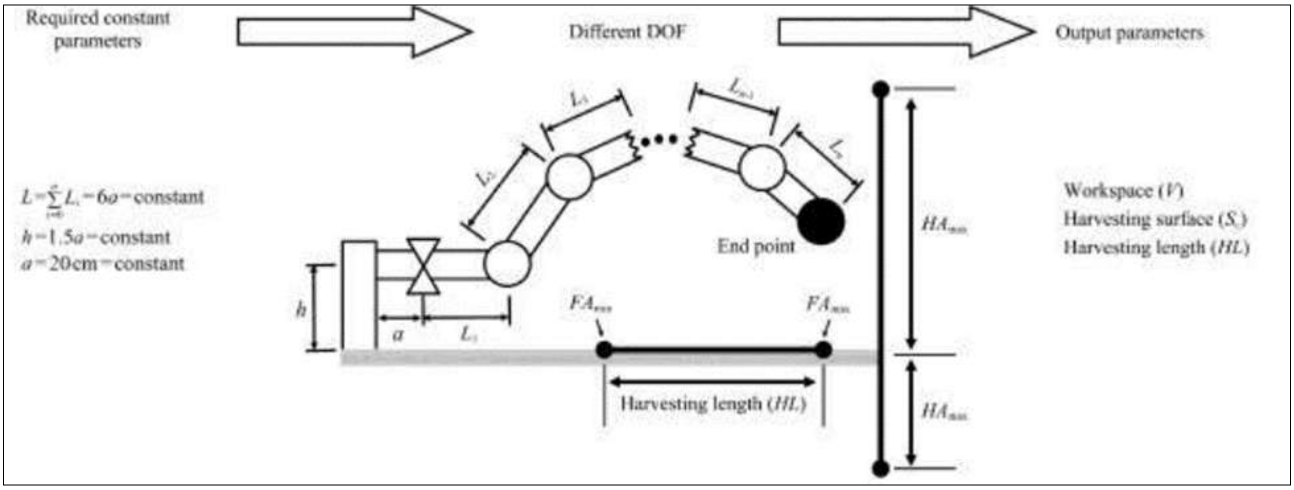


Fig 7: DOF optimization

The system's average repairability was found to be ±0.51 mm. In addition, the findings showed that the average system error was adequate for the stated application, and the robotic arm had sufficient precision to harvest a heavy-weight crop. Due to algorithmic behaviour, the inaccuracy might be decreased to one millimetre over short distances. This demonstrates the robot's ability to do precise manoeuvres. It will be necessary to repeat these trials in real-world conditions to determine if vibration affects performance. The characteristics of the actual world are anticipated to boost the accuracy and repeatability levels.

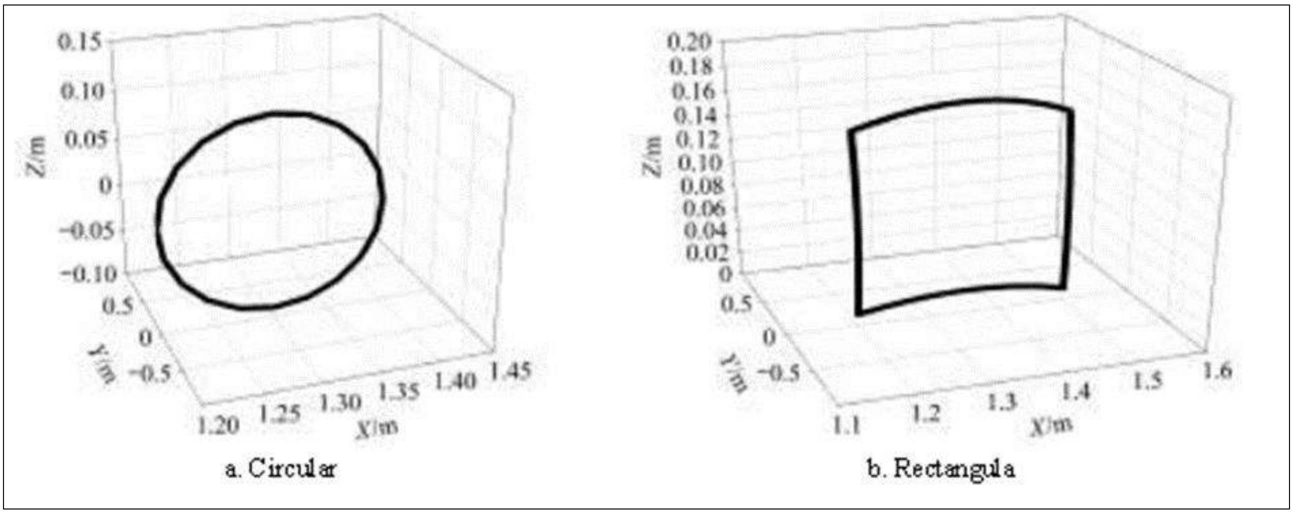


Fig 8: Analysis results of Circular and Rectangule

The construction of the robotic arm was created after discovering the optimal DOF. It was built with a 1.83 mm *FA*, a 1.43 m *HL*, and a 17.25 m3 *Vn* as illustrated in Figure 21a. As a result of the production process, various constraints such as faults in the manufacturing process, joint limits, and component interferences lowered the necessary parameter (from designed system). Figure 21d shows that the final system's *FA*, *HL*, and Vn were 2.024 m, 1.36 m, and 8.27 m3, respectively. The *Sc,mx* of the final RAVeBots-1 has been obtained at 3.52 m2, which solely pertains to the intended robotic arm placed on the robot tractor without any end effector. (Figures 21c and 21d).

FA, *HL*, *Sc*, *max* and *Vn* rose from 2.93 mm to 1.48 m, 6.37m2 to 12.06m3 when the end-effector was installed. There were no issues with harvesting crops based on these values.

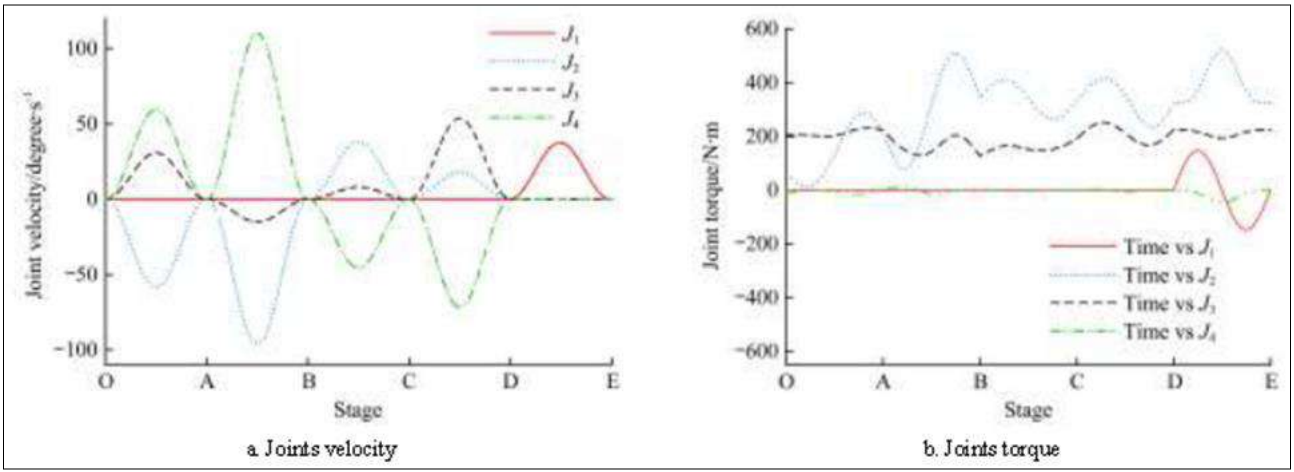


Fig 9: Analysis results of joints velocity and joints torque

5. Conclusions

The creation of a robotic arm for heavy-duty use is described in this paper. To harvest pumpkin, watermelon, and melon, which are all considered heavy crops, an actuation unit was developed and installed on a robot tractor. In the end, the produced system's physical requirements were measured. For the developed system (without an end-effector), the front access, harvesting length, and workspace volume were found to be 2.024 m, 1.36 m, and 8.277 m3, respectively. A total of 2.93 millimetres (FA), 1.48 meters (HL), and 12.06 cubic meters of volume (Vn) were added to the system when the end-effector was installed. To harvest pumpkins, RAVebot-1 was able to satisfy all of its criteria, according to the final system specifications. We hope that the RAVebots-1 will be used in daily agricultural activities, particularly for harvesting heavy-weight crops. In addition to harvesting tasks, this agricultural robot can measure crop physical attributes (weight, volume, density, etc.). As an intelligent agricultural robot, it can also irrigate, sow, fertilize, and remove weeds.

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