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Development of Arm-Robot for Harvesting of Agricultural Products

A Kinematics Analysis of Arm Robot by Roboanalyzer

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Abstract

With robots, the repetitive, difficult and dangerous work by human can be done by robots and is even very accurate. As well as in agriculture, many repetitive and difficult jobs such as picking (harvesting) lots of fruit that are difficult to reach can be done by robots.

To develop robots that can do work in agriculture field, it is necessary to design and analyze and of course be tested on agricultural products. For this reason, it is necessary to design a robot that can pick agricultural products (harvesting). This research begins with mechanical and electronic analysis, then assembly design and test. The purpose of this study is to design a simulator for fruit harvesting arm-robots.

The robot is developed with an object retrieval system with a robot arm mechanism. Based on the results of research and simulators, the conclusions are The robot can reach according to the specified position, as is the solution of various alternatives with robot kinematics analysis, $\theta 1$=63.6457°, $\theta 2$=-29.1984 dan $\theta 3$=-51.3513° and $\theta 1$=63.6457°,2=-68.9913° and $\theta 3$=51.3513° end-effector position is px=15 ,py=25 and pz=0.0. Thus the results of the analysis can be developed on the robot to reach the location of the fruit or object to be picked.
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Keyword: arm-robot, agriculture, robot, roboanalyzer

1. Background

Indonesia is an agricultural country that produces a lot of agricultural products, these products are very diverse and need proper handling after harvesting (especially that produce fruit). And of course, it really needs machines that can increase productivity, and harvesting and handling post-harvest agricultural products can be done better.

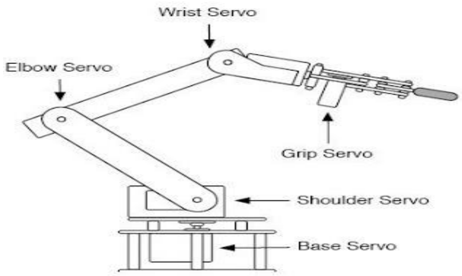
It is necessary to develop machines that are smarter and capable of carrying out activities that require decision making and repetitive work such as harvesting agricultural products. These machines include robots. The robot is designed to work automatically and is capable of performing selective and repetitive jobs as is usually done by humans. Robots designed to perform tasks in agriculture are referred to as agricultural robots.

With robots, very difficult work/jobs, and dangerous jobs that are done directly by humans, can be done by robots and accurate.

To develop robots that can do work in agriculture, it is necessary to design and analyze and of course try it on agricultural products, especially for picking work.

2. Arm Robot

A robot arm is a robot that resembles a human hand which movement of the arm itself, can be replace by a servo motor, DC motor or AC motor.



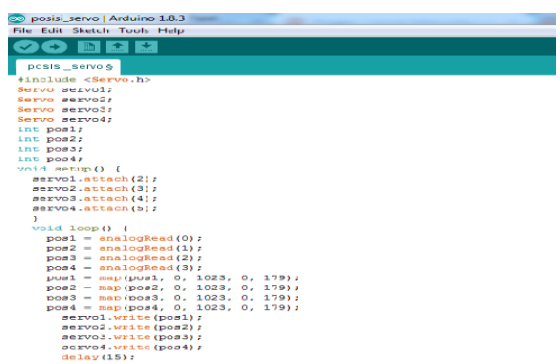
The minimum system of a robot consists of at least 4 or 5 servo:

1. Base servo: The base turns right or left
2. Shoulder servo: The part of the arm that moves up or down
3. Elbow servo: The elbow of the robot functions the same as the robot arm
4. Wrist Servo: The wrist moves up and down
5. Grip Servo: Servo part that serves to clamp the workpiece

Figure 1. Implementation of arm-robot in industry

Technological developments and sales competition that led to the many arm robots/hand robots being more affordable in terms of price opened up the possibility of their use in all sectors including the arts and crafts sector of various materials. The Arm-Robot can make objects that do not need to be set on the platform. There are several types of Robot Arm

1. Cartesian Robot. Usually used for assembly work such as picking up then placing, applying sealants or welding. Consists of 3 prismatic joints whose axes are coincident with the Cartesian coordinator.
2. Cylindrical Robot. Cylindrical robots are also used for assembly, handling, spot, gas and arc welding. The axes used form a cylindrical coordination system.
3. Spherical Robot. This robot-arm is used for handling machinery, spot welding and etc. The axis of this robot uses an axis that forms a polar coordination system.
4. SCARA robots. This robot is also used for assembly, machining handling, pick up and place work with 2 rotary joint features that produce adjustments to the plane.
5. Articulated robot. This robot with at least 3 rotatable joints can be used for various tasks ranging from assembly, fettling, gas welding and so on.
6. Parallel robot. This rotating or concurrent prismatic joint robot is commonly used in airplane simulators.
7. Anthropomorphic robot. This robot is known as a robot that imitates the shape of a human hand, has fingers and joints like arms




```
#include <Servo.h>
Servo servo1;
Servo servo2;
Servo servo3;
Servo servo4;
int pos1;
int pos2;
int pos3;
int pos4;
void setup() {
  servo1.attach(2);
  servo2.attach(3);
  servo3.attach(4);
  servo4.attach(5);
  }
  void loop() {
    pos1 = analogRead(0);
    pos2 = analogRead(1);
    pos3 = analogRead(2);
    pos4 = analogRead(3);
    pos1 = map(pos1, 0, 1023, 0, 179);
    pos2 = map(pos2, 0, 1023, 0, 179);
    pos3 = map(pos3, 0, 1023, 0, 179);
    pos4 = map(pos4, 0, 1023, 0, 179);
      servo1.write(pos1);
      servo2.write(pos2);
      servo3.write(pos3);
      servo4.write(pos4);
      delay(15);
}
```

3. Kinematic Control

Robot Kinematics Control is expressed as a kinematics controller because it contains a component of the transformation of the

Cartesian space to the joint corner space and vice versa

There are two kinematics concepts, namely Forward Kinematics and Inverse Kinematics.

a. Forward Kinematics

Forward Kinematics is a method for determining the orientation and position of the end-effector from the magnitude of the joint angle and the link length of the robot arm. The forward kinematics equation is obtained based on the number of DoF and the kinematic type of chain robot manipulator.

b. Inverse Kinematics

Inverse kinematics will be more frequently used in the manufacture of robot arms because in real robot use, joint-joint arrangements are no longer prioritized. The main focus is how the end-effector achieves the position of the object properly based on the placement of predetermined coordinate references.

in the kinematic inverse it can be solved by several techniques. The methods most commonly used are matrix algebraic, numerical approximations, and trigonometric equations.

Kinematics with respect to robotics, the first to get attention is the rotation matrix and the transformation matrix. A rotation matrix is a matrix that maps a vector or position in one coordinate system to another in a rotational motion. Transformation matrix is a matrix that maps a vector or position in one coordinate system to another coordinate system with respect to rotation, translation, scaling and perspective / point of view.

Kinematics in calculating the movement of a robot arm is very necessary apart from being seen from the dynamic side because kinematics is the basis for making the controller/drive unit of the robot. By studying the kinematics, the design of a robot model can be made according to the kinematics calculation in order to obtain the appropriate reference angle, position, and orientation. Another important thing is the effect on the accuracy and precision of placing the end-effector on the robot and its orientation. By moving each joint at a certain angle, you will get an end effector with a certain position and orientation

Control System

The control system can be said as the relationship between the components that make up a system configuration, which will produce the expected system response. The control system is known as an open loop system and a closed loop system. Open loop control systems generally use controllers and control actuators which are useful for obtaining good system response. The output of this control system is not recalculated by the controller. A state whether the process has actually reached the target as desired input or reference, can not affect the performance of the controller.

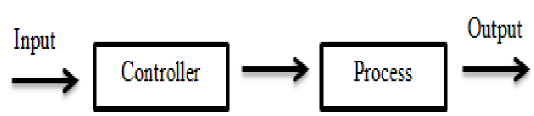


Figure 2 Diagram Block System of Control *Open Loop*

Unlike the open loop control system, the closed loop control system uses a variable that is proportional to the difference in response that occurs to the desired response. Such a system is also often known as a feedback control system (feedback system).

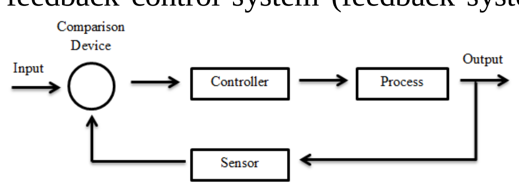


Figure 3 Diagram Block System of Control *Closed Loop*

4 Actuator

Brush DC motors are one of the most widely used actuators in industry or robot manipulator systems. This motor uses the electromagnetic principle to produce work, namely rotation. The DC motor consists of a rotating rotor and a magnetic part as a stator (the stationary part). The current coming through the brush and the stator magnetic field will cause the rotor to rotate. The magnetic part of the stator uses permanent magnets. The direction of current coming to the rotor affects the direction of the DC motor rotation.

DC motors are often applied especially to robotic systems that require high torque because they can add a gear reduction to increase torque. In addition, changing the speed of a DC motor is quite easy, namely by using a PWM signal. It's just that closed loop position and speed control cannot be applied directly to a DC motor because it still requires a position sensor as a feedback for the value of the position and rotational speed of the DC motor.

5. Censor as Feedback

The use of a potentiometer for position control is quite practical because it only requires one excitation voltage and usually does not require a complicated signal processor. However, the use of a potentiometer as a position sensor must be tested first in relation to its linearity and hysteresis characteristics.

Linearity states how linear the relationship between the sensor measurement values is and the actual value in the environment. Meanwhile, hysteresis states how close the reading graph goes up and the reading graph drops the sensor under the same conditions. The ideal condition is achieved when the relationship between the sensor readings and the actual value in the environment forms a linear graph and the graphs of up and down readings coincide.

The test will determine how linear and how big the potentiometer hysterias error is. Then additional measures are required to determine the true physical value of the measured reading values. After that, the potentiometer can really be used for the process measurement.

The microcontroller is arranged in one chip where the processor, memory and I/O integrated into a single unit control system so that the microcontroller can be said to be a mini computer that can work innovatively according to system requirements. In its application, it is the microcontroller that is directly related and has the task of controlling the manipulator robot. However, to support industrial robot applications as flexible automation, the use of a microcontroller is usually paired with a computer that can communicate with each other in sending data both to reprogram tasks carried out by the microcontroller and to assign values to the parameters on the microcontroller so that the manipulator can be controlled from the computer.

6. Development of Robot System

The robot developed is a robot that will be used for the picking process with an end-effector, DC motor, microcontroller, and 12 Volt dry batteries.

Figure 4 Rancangan End-efector

Specification of Robot

The specifications are needed to determine the size of each unit in the robot. Each unit has a predetermined function and layout position to form a structured robot. Then the specification of the robot is related to kinematic because it takes the value of each unit length of each part of the robot, especially in the robot arm and the base

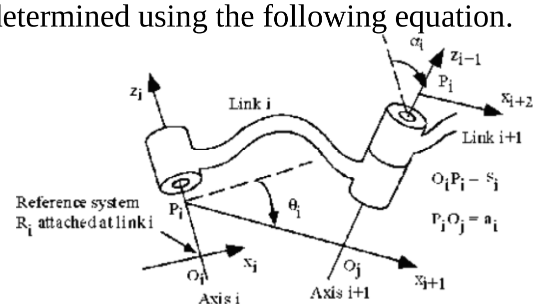
plane, which is needed to determine the length of the robot arm, and the position of the end effector point on the robot and the determination of the zero point to be determined on the robot. Also the value in the robot specification is used to determine the workspace area of the robot so that in implementing kinematic science the robot movement becomes directed and in order to know the maximum and minimum movement limits of the robot.
The following are the specification values needed for Kinematic: Arm Length 1st = 10 cm
Length Link 2nd = 23 cm,
Griper length = 15 cm
There are 3 stepper motors, 3 L298N drivers and 3 position sensors, namely a potentiometer and 1 micro servo and a supply source.

a. Where each component has its own function and in general the working principle of the schematic that has been designed on the robot is as follows:
b. a. The L298N driver is used to control the movement of the motor, either Counter Clockwise or Clockwise, as well as the PWM signal connector that we set from the Arduino microcontroller to the motor.
c. b. Supply 8.2VDC, we set the value of this supply based on the input voltage specifications on the motor based on the value stated on the motor datasheet.
d. c. The DC motor is used as an actuator to drive the robot arm.
e. d. The potentiometer is used as feedback from the actuator to determine the position of the DC motor.
f. e. Micro Servo DC is used as a control griper on the robot arm which serves to clamp an object that has been set in a specified position

4. Analysis and Testing

Kinematic Forward

The robot arm simulator consists of several links and joints. Joints are used to connect any existing links where each joint represents one degree of freedom. To describe the translational and rational relationships between adjacent links, the Denavit Hartenberg (DH) parameter method is used as a matrix method that systematically builds a coordinate system of each link. Based on the DH parameter, then the transformation of the matrix for each frame coordinate from link i to i + 1 can be determined using the following equation.



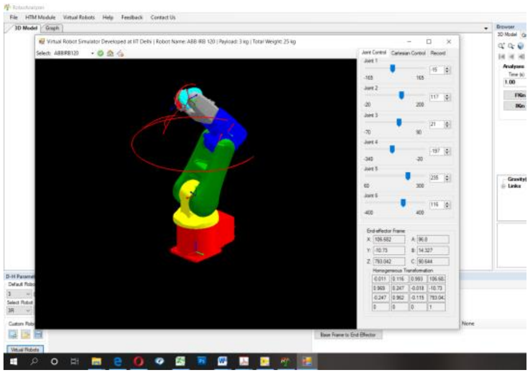
$$ {}^{i-1}_{i}T = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_i & \sin\theta_i\sin\alpha_i & a_i\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_i & -\cos\theta_i\sin\alpha_i & a_i\sin\theta_i \\ 0 & \sin\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Figure 5 DH parameter Matrix Simulator *Arm robot*

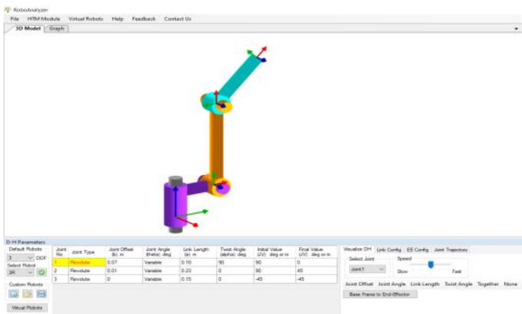
Roboanalyzer

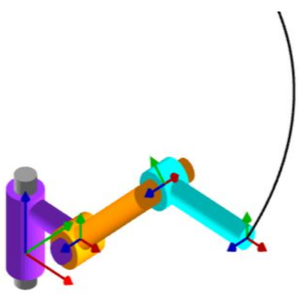
There are 3 types of joint rotation, with 7 cm joint offset and 90 ° twist angle at the first joint. The length of the first link is 10 cm, the second link is 23 cm and the third link is 15 cm.
In this study, the type of simulation model used is the 3R Articulated Model, which is shown in Fig
There are 3 types of joint rotation, with 3 cm joint offset and 90 ° twist angle at the first joint. The length of the first link is 3 cm, the second link is 9 cm and the third link is 13

cm



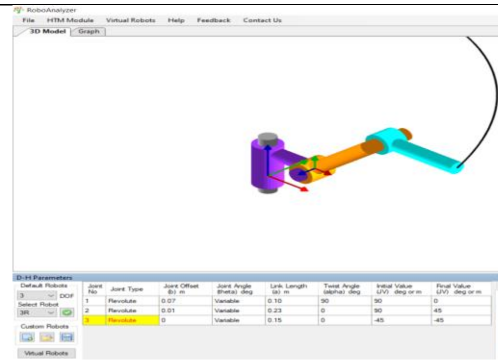
And the result of the transformation of the matrix for each link is





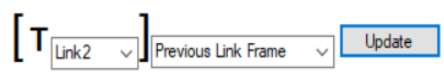
Joint No	Joint Type	Joint Offset (b) m	Joint Angle (theta) deg	Link Length (a) m	Twist Angle (alpha) deg	Initial Value (JV) deg or m	Final Value (JV) deg or m
1	Revolute	0.07	Variable	0.10	90	90	0
2	Revolute	0.01	Variable	0.23	0	90	45
3	Revolute	0	Variable	0.15	0	-45	-45

Figure 6. Spesifikasi Robot yg dianaisis



$$\begin{bmatrix} 1 & 0 & 0 & 0.1 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0.07 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 13 Transformation Matrix base Frame dengan link Pertama



$$\begin{bmatrix} 0.707107 & -0.707107 & 0 & 0.162635 \\ 0.707107 & 0.707107 & 0 & 0.162635 \\ 0 & 0 & 1 & 0.01 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 8 Transformation Matrix First link and Second Link

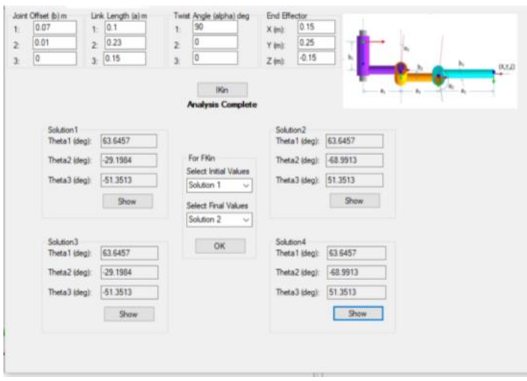
$$\begin{bmatrix} 0.707107 & -0.707107 & 0 & 0.162635 \\ 0.707107 & 0.707107 & 0 & 0.162635 \\ 0 & 0 & 1 & 0.01 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 9 Transformation Matrix Second Link and Link 3

$$\begin{bmatrix} 0 & 0 & 1 & 0.01 \\ 0.707107 & -0.707107 & 0 & 0.206066 \\ 0.707107 & 0.707107 & 0 & 0.406066 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Figure 10. Transformation base frame & Link 3

From the results, the transformation matrix between the base frame and the link 3 is obtained, which is the result of the matrix transformation of each link. Measurement in meters



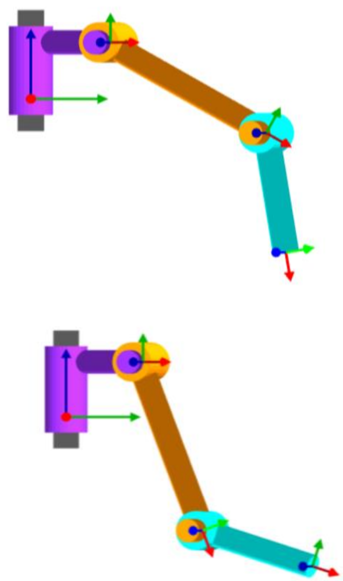


Figure 11. Solusi (1) dan (2)

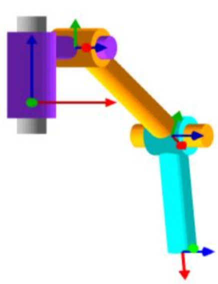
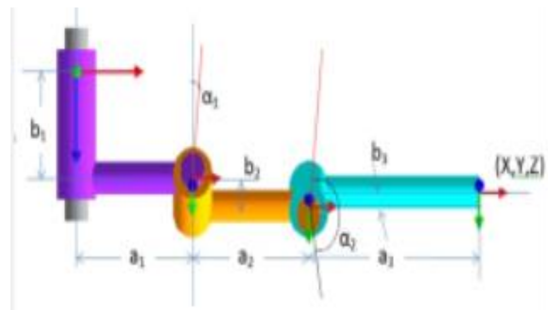


Figure 12. Solusi (3)

Table 1. Solusi Posisi/sudut Posisi Akhir efektor

delta	Solusi 1	Solusi 2	Solusi 3	Solusi 4
1	63.6457	63.6457	63.6457	63.6457
2	-29.1984	-68.9913	-29.1984	-68.9913
3	-51.3513	51.3513	-51.3513	51.3513

From the simulation results obtained 4 solutions or angles that make the final effector reach the position px = 15, py = 25 and pz = 0.0. The solution is.



a) $\theta1$=63.6457°, $\theta2$=-29.1984 dan $\theta3$=-51.3513°.
b) $\theta1$=63.6457°,2=-68.9913° dan $\theta3$=51.3513°.
c) $\theta1$=63.6457°,2=-29.1984° dan $\theta3$=-51.3513°.
d) $\theta1$=63.6457°, $\theta2$=-68.9913° dan $\theta3$=51.3513

From these results, it is possible that the movement that can be carried out by the robot is one (1) or two (2) alternative which does not obstruct the funds against trees or plants, because these movements also do not touch the physical parts of the robot.

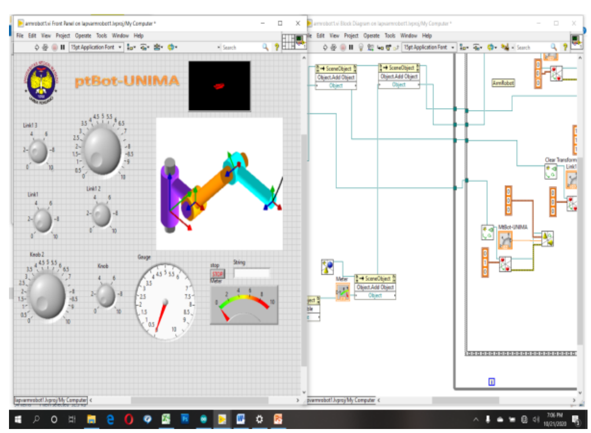


Figure 13. Interface Robot by LabView

Figure 14 Process of input command/statement with app-Arduino

Figure 15. Simulation Arm Robot

5. Conclusions and Recommendations

5.1 Conclution

Based on the results of research and simulation, the following are conclusions: Robot can reach the object according to the specified position, as the solutions of various alternatives $\theta 1$ = 63.6457°, $\theta 2$=-29.1984 and $\theta 3$=-51.3513° and $\theta 1$=63.6457°, 2=-68.9913° and $\theta 3$=51.3513° where the end-effector position can reach the position px = 15, py = 25 and p = 0.0. The results of the analysis can be developed on the robot to reach the location of the fruit or object to be picked.

5.2 Recommendations

1. There needs to be a design of a robotic arm capable of lifting and clamping objects that meet the minimum standards for fruit weight or yield by adding a device / robot arm capable of removing or distinguishing non-fruit / agricultural products / objects
2. Further research is needed for the implementation of various types of objects and developed to be able to recognize / identify the color or level of fruit maturity

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