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Pattern recognition based movement control and gripping forces control system on arm robot model using LabVIEW

Abstract

Most arm robot has an inefficient operating time because it requires operator to input destination coordinates. Besides, main problem of arm robot is object's vulnerability when it is manipulated by the robot. This research goals is to develop an arm robot control system which has ability to automatically detect object using image processing in order to reduce operating time. It is also able to control gripping force for eliminating damage to objects caused by robot gripper. This research is implemented in LabVIEW 2011 software to control arm robot model which can represent industrial scale robot. The software is designed with informative visualization to help user learn and understand robotic control concept deeply. The system can automatically detect object position based on pattern recognition method which has four steps: pre-processing process to initialize picture taken by camera, segmentation process for separating object from the background, classification process to determine characteristics of object, and position estimation process to estimate object position in the picture. The object's position data are then calculated by using kinematic equation to control the robot's motion. The results show that the system is able to detect object and move the robot automatically with accuracy rate in x-axis is 95.578 % and in y-axis is 92.878 %. The system also implements modified PI control method with FSR as input to control gripping force with maximum overshoot value <10 %. Arm robot model control system developed is successfully meet the expectation. The system control can be implemented to industrial scale arm robot with several modification because of kinematic similarity between model and industrial scale robot.

Keywords: arm robot model; LabVIEW based software; pattern recognition for position estimation; FSR based gripping force control.

I. Introduction

Robots are required to complete difficult human task, such as high accuracy task, high risk task, repetitive task or some tasks that require amount of energy [1]. Arm robot often called industrial robot (defined by ISO 8373) is widely used in the industry [2] especially in pick and place task [3]. Arm Robot is reliable for pick and place task because it is considered capable of replacing human arm [4]. In order to develop an efficient arm robot control system without damage risk, the control system should be tested and implemented to arm robot model [5]. Arm robot models can represent a large scale (industrial scale) arm robot because they have the same degrees of freedom and kinematics parameter, although they have different dimensions and specifications.

Many studies of robot arm start with implementing the system control to robot model or lab scale robot to ensure the system control performance without risking the use of ~~industrial scal~~e robot. Design of small-scale arm robot model for pick and place mission is studied by A. R. Al-Tahtawi *et al.* [6]. Study by Wong Guan Hao *et al.* [7] is implementing PC based Control to five degree of freedom (5 DOF) arm robot. M. J. Ansari *et al.* [8] study and develop microcontroller-based Arm robot control system. Arm robot programming in LabVIEW has been done in previous study by R. S. Pol *et al.* [9]. The Robotic Arm runs in three different modes: manual mode, semi-autonomous mode, and autonomous mode. Another study by P. Andhare [10] gives an idea about finding the x, y coordinate of object by converting pixel coordinate from camera into real world coordinate with the help of 2D transformation. The study incorporates robotic arm controller based on location and orientation of object.

In this study, control system software is created using LabVIEW 2011 software and implemented on the arm robot model with four degrees of freedom. Previous study only focuses on controlling the robot with control system software they built. This study not only focus on control system but also concern in forward kinematic and inverse kinematic data visualization to help user learn and understand robotic control concept deeply. This study not only develop basic arm robot control system but also implement advanced control system so the robot has ability to automatically detect object using image processing in order to reduce operating time and has ability to control gripping force for eliminating damage to objects caused by robot gripper.

Object identification process can be executed automatically by the system with pattern recognition process using 3.0 MP camera as sensor. The object recognition coordinate data is calculated with kinematics equations to determine the angle of each joint and then moving the robot. The experiment data that will be taken are about the accuracy of the robot movement in the x and y axis toward the object.

The force controlling process is important in charge of completing the object moving task. The forces generated during gripping process must remain within the tolerance limits to avoid damage to the object. The object gripped by robot is limited to small ball-shaped object. The force that will be controlled is only the force on the gripper surface which is generated from the interaction between the robot gripper and the object.

II. Materials and Methods

The system architecture consists of six main sections, such as the camera, the force sensor force sensing resistor (FSR), the PC with software NI LabVIEW installed, serial servo controller (SSC), signal conditioning circuit, and Arm Robot model with four degrees of freedom. The system architecture design shown in Figure 1.

Objects on work area/region of interest (ROI) with light intensity about 700-1000 lux will be captured by the camera. In this study the camera position is fixed. Another method by attaching camera on robot end-effector will not discussed here [11]. To ensure sufficient light intensity, the system comes with light bulb as additional light source. The image data of the camera is represented by an electrical signal at each pixel in the camera sensor. The information output of the image is in a matrix form which is ready to be processed further on the PC. Image processing purpose is to obtain information of the decided object's characteristics, which is subsequently used in the position estimation process. Finally, the position information is used as the desired coordinate for the end effector of robot model. The data are transmitted via serial interface from a PC to SSC of arm robot model [12].

The system controls the gripping forces with modified PI control method. The sensor's measurement results will be used as the feedback input of the control system. PI control will generate voltage values to control the PWM value which is generated by the SSC for controlling the servo gripper position. The control system software based on LabVIEW will communicate both ways with the SSC to acquire sensor data and to control servo motor.

The Figure 2 shows the algorithm flowchart of the desired system. First step is pre-processing process to initialize picture taken by camera. Then, the system executes segmentation process for separating object from the background by using thresholding and edge detection algorithm. Next, the system will run classification process to determine characteristics of object, and then estimate object position in the picture. The object's position data are then calculated by using kinematic equation to control the robot's motion.

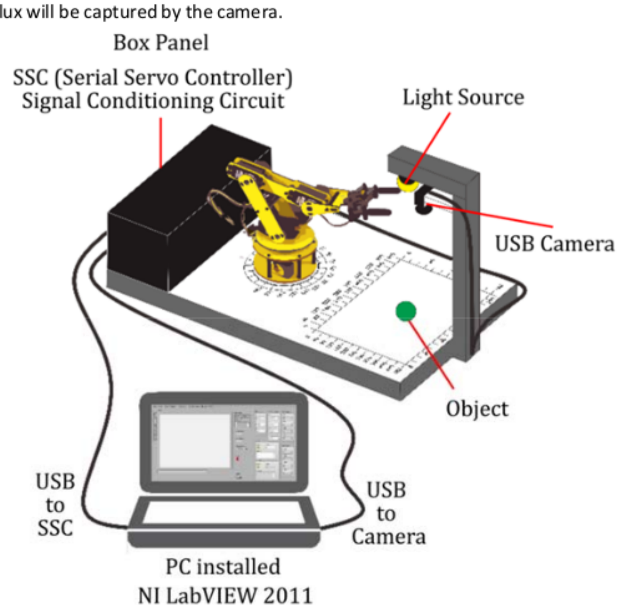


Figure 1. System design (source: personal collection)

System model is needed for calculating and simulating the system behavior before being implemented in actual system. The robot model physically has five main parts. They are the base, waist, upper arm, forearm, and gripper. Schematic model of the robot describing the physical part of the robot is shown in Figure 3.

From the physical part model schematic, it can be simplified into the stick diagram model for calculation and kinematic analysis. Figure 4 shows stick diagram model of the robot. The stick diagram represents joint and link connection of the robot model. Base joint or waist shown in schematic model is represented in stick diagram as θ_1 (*theta 1*). Waist length or base height in schematic model is represented in stick diagram as l_1 (*length 1*). For shoulder joint, elbow joint, wrist joint, they are represented as θ_2, θ_3, and θ_4. Otherwise, upper arm, forearm, and gripper length are represented as l_2, l_3, and l_4 in in stick diagram.

The robot model is now defined. The next step is determining the system control so the robot has ability to grip the object automatically from image data and control the gripping force. The system can automatically detect object position based on pattern recognition method which

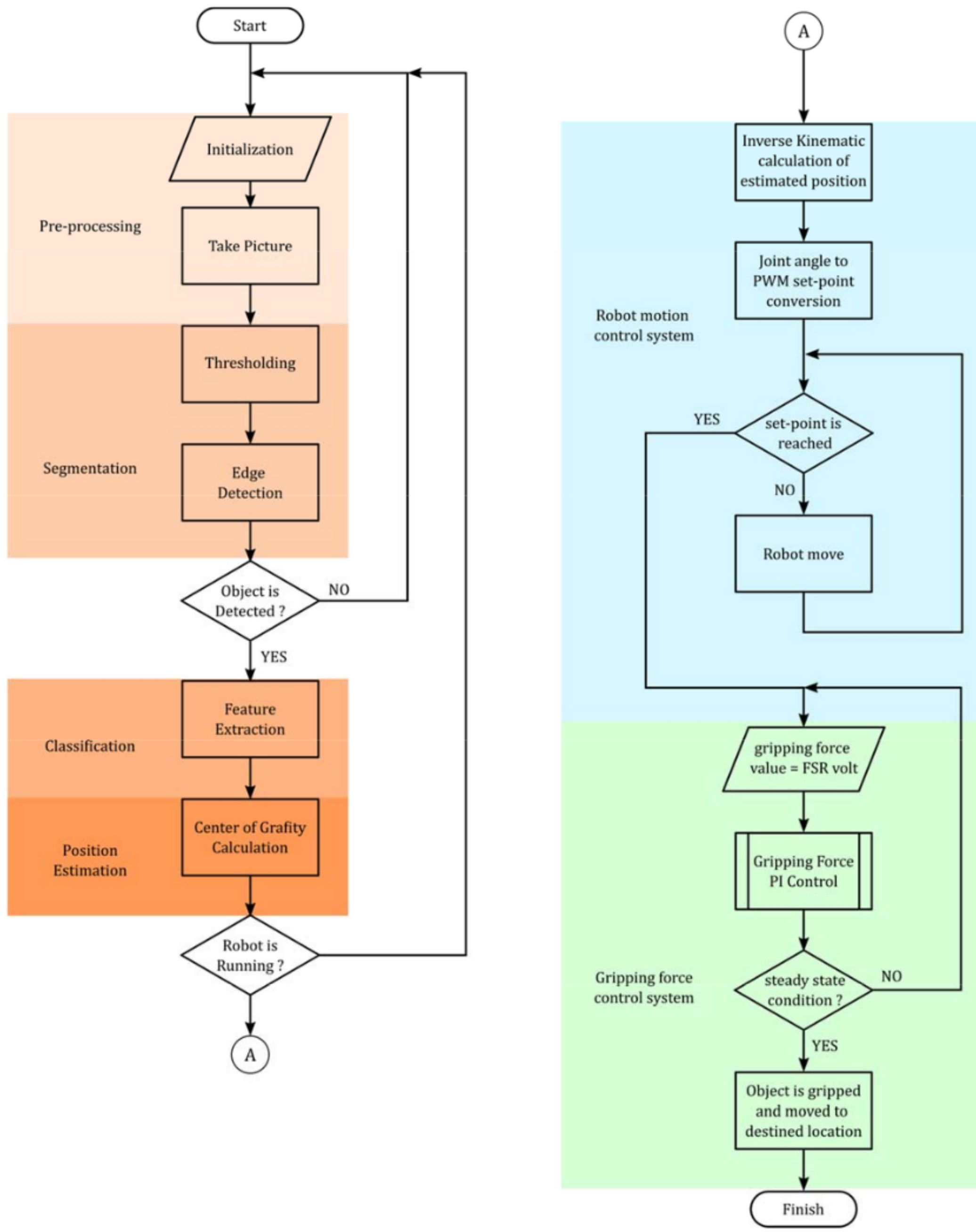


Figure 2. Algorithm flowchart

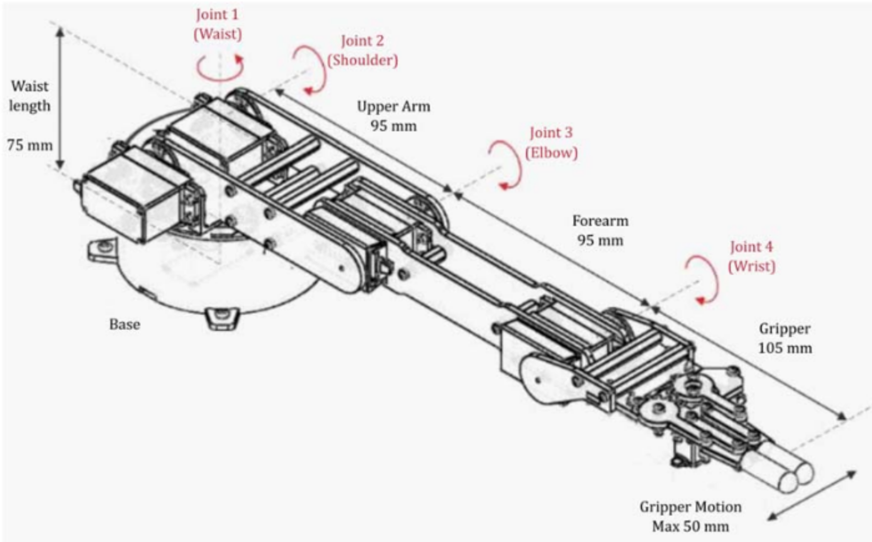


Figure 3. Schematic model of the robot (source: personal collection)

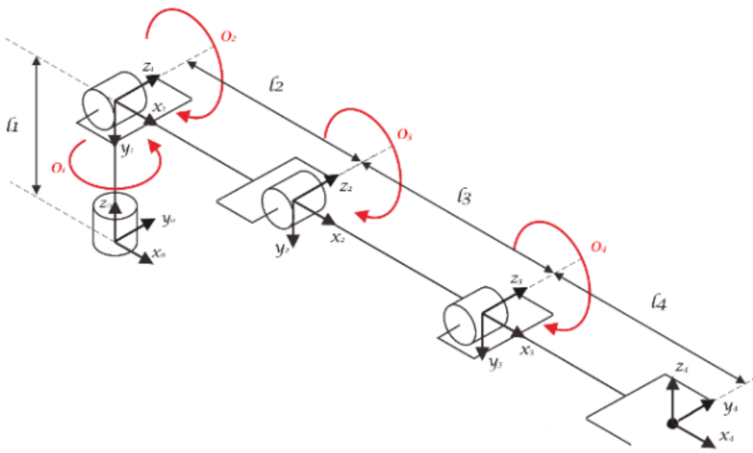


Figure 4. Stick diagram model (source: personal collection)

has four steps. Pre-processing process to initialize picture taken by camera, segmentation process for separating object from the background, classification process to determine characteristics of object, and position estimation process to estimate object position in the picture [13].

A. Pattern recognition

1) Pre-processing

Dark-colored objects on the work area are captured visually by the camera which have resolution of 3.0 MP. The center point of the camera lens is coaxial with the center point work desk. The camera position is adjusted so it can produce an image with 480x640 pixels size. This is equal to 160x213.33 mm2 of the work area.

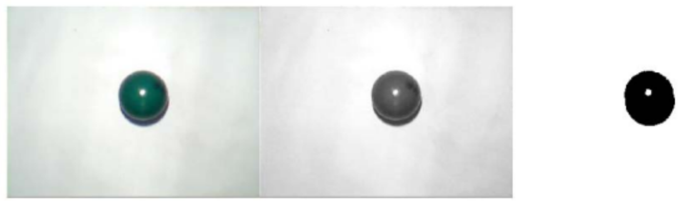
2) Segmentation

Before segmenting process, image data is converted from RGB or CMYK format into gray-scale format. Segmentation is a process of changing the image of the gray-scale format into a binary image by using one or more limit values to separate objects with the background of the image. Limit value defined number as the limit used in segmentation operation is called threshold. Figure 5 shows the steps of segmentation from a picture.

3) Classification

Classification aims to determine the object from an image by using feature extraction. Feature extraction is the process to determine the characteristics of the object from the obtained image data. Feature extraction was conducted on the determination of the outermost point on the x-axis and on the y-axis. The system extracts the feature from image and define it as object by finding the connected pixel.

To define what is meant by a connected pixel, it is first necessary to define what is meant by connectivity. For that purpose, there are rules that says the pixel A with the image pixel coordinates (r, c) is adjacent to four pixels on pixel coordinates (r-1, c), (r+1, c), (r, c+1), and (r, c-1). In other words, every pixel A image (except the one at the edge of the image) has four neighbors: the pixel directly above, directly below, directly to the right and directly to the left of pixel A. This relationship is often referred to as 4-connectivity. If we



(a) (b) (c)

Figure 5. (a) Image captured from camera; (b) Grey-scaled image; (c) Segmented image (source: personal collection)

extend the definition of adjacency to include pixels that are diagonally adjacent (i.e. pixels with coordinates (R-1, c-1), (r-1, c+1), (r+1, c-1), and (r+1, c+1)), then we say that adjacent pixels are 8-connected [5]. Figure 6 is example illustration of the pixel from image in classification process. The pixel with X value is connected with neighbor pixel which has same value. All pixel connected each other is defined as an object (an object shown in same color in Figure 6). The desired system control tries to find round object with 40 mm diameter.

4) Position estimation

The main purpose of image processing in the system is to get position and orientation of the object in real world. To define the position of an object determined the center point of the object using the center of gravity (CoG) calculation. Position estimation get the position vector object origin position OO related to the origin of the work area coordinate frame OA. Then the position coordinate is translated form the work area coordinate frame to the robot base coordinate frame OR.

Cartesian axis of working area is in same direction with pixel distribution in picture taken by camera. Otherwise, x-axis of robot frame is parallel with y-axis of working frame while y-axis of robot frame is parallel with x-axis of working frame. Estimated position of the object refers to the x-axis of the robot obtained from the calculated data position at the y-axis in the image information, while estimated position of the object refers to the y-axis of the robot obtained from the calculated data position at the x-axis in the image information. See reference frame of the system in Figure 7 to understand the work area frame and the robot frame correlation.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0
0	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0
0	X	X	X	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	X	X	0	0	0	0	0	0	0	0	0
0	0	0	0	0	X	0	0	0	X	X	X	0	0	0	0
0	0	0	0	0	X	0	0	0	X	X	X	0	0	0	0
0	0	0	0	0	X	X	X	X	X	X	X	0	0	0	0
0	0	0	X	X	X	X	X	X	X	X	X	0	0	0	0
0	0	0	X	X	X	X	X	X	X	X	X	0	0	0	0
0	0	0	0	0	0	0	X	X	X	X	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0
0	0	0	0	0	0	0	0	0	0	0	0	X	X	X	0
0	0	0	0	0	0	0	0	0	0	0	0	0	X	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6. Pixel image illustration in classification process (source: personal collection)

B. Arm robot movement

The robot which is used in this study is a robot model that has four degrees of freedom plus one gripper. Input data is given to the robot as PWM set-point for each joint, and then the data will be processed by the SSC, while the position control process carried out by the internal control system of the robot which is known as servo motor. The following discusses about internal robot control, physical and movement part, modelling, forward and inverse kinematics equation, and robot force control.

1) Position control

Position control system is used in the system to control the angle position of each joint. The actuator used in the robot is DC servo motors which have internal control system. Servo control system is a proportional control system with PWM set-point as the input, and uses motor angle which is obtained from the potentiometer as the feedback. Each servo which is used at each robot model joint have different characteristics. Measurement and experiment of each servo motor attached to the robot joint are done and the relationship between the PWM set-point and the angle of each joint is obtained. Figure 8 shows the correlation between PWM set-point with joint angle formed from each robot joint.

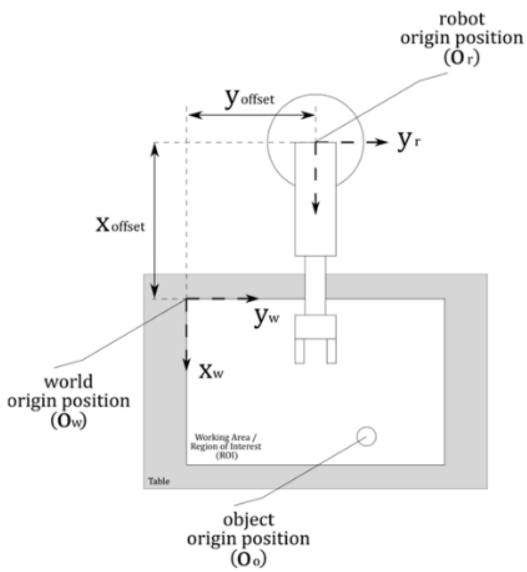


Figure 7. Reference frame of working area and the robot (source: personal collection)

Set-point formulations of each joint angle and joint range of the robot taken from experiment and measurement are shown in the following Table 1. Data shown in angle range column is the reachable angle of robot model mechanical construction. Otherwise set point formulation column is the result of linear regression function from joint angle measurement. The formulation is important because it will be used by control system to determine output of PWM duty cycle for controlling each joint angle of the robot model.

2) Forward kinematics

Forward kinematics is equations of a robot to compute the position of the end-effector from specified values for the joint parameters. The type of arm robot used is the articulated type (RRR). The forward kinematic calculation of this type of arm robot results in the final orientation and position coordinates of the magnitude of the angle values formed by each joint (joint) of the robot which are integrated in a series of kinematic chain.

Standard procedure called Denavit-Hartenberg (D-H) is used to define each robot joint with respect to the reference frame coordinates and to transform systematically using a transformation matrix [5]. Then there are homogeneous coordinates and homogeneous transformation for simplifying transformations on coordinate frames. D-H procedure is used to describe the link relationship of the robot where the link is assumed as a rigid body. Each link-i has a coordinate frame, and each coordinate frame is

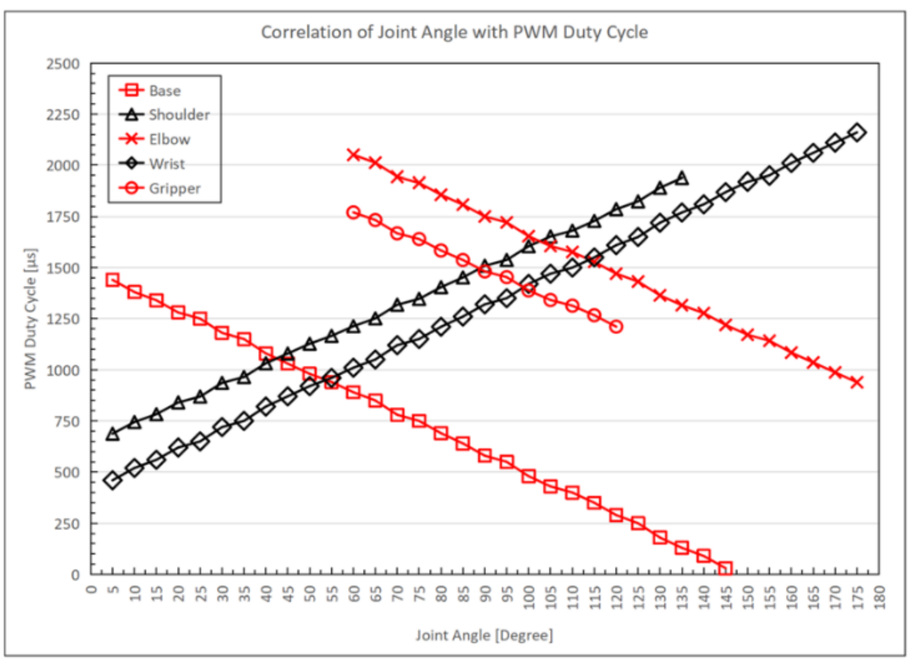


Figure 8. Correlation of robot joint angle with PWM duty cycle set-point

determined based on the right-hand rule. The four characteristic parameters of joint-i and link-i used in D-H procedure are link length, link turnover, link offset and joint angle these names come from a specific aspect of the geometric relationship between the two coordinate frames. The following Table 2 shows D-H parameters which are obtained by modeling a robot that has been presented in the system design.

From the D-H parameters that have been defined, the homogeneous transformation equation can be determined. Homogeneous transformation is a relationship function between the coordinates of the end effector and the reference coordinates of the base robot [5].

$$H = T_n^0 = A_1(\theta_1) \ldots A_n(\theta_n) \quad (1)$$

$$T_4^0 = A_1(\theta_1) * A_2(\theta_2) * A_3(\theta_3) * A_4(\theta_4) \quad (2)$$

$$A_n(\theta_n) = \begin{bmatrix} R_n^{n-1} & O_n^{n-1} \\ 0 & 1 \end{bmatrix} \quad (3)$$

$$A_1(\theta_1) = \begin{bmatrix} c_{\theta_1} & 0 & -s_{\theta_1} & 0 \\ s_{\theta_1} & 0 & c_{\theta_1} & 0 \\ 0 & -1 & 0 & l_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

$$A_2(\theta_2) = \begin{bmatrix} c_{\theta_2} & -s_{\theta_2} & 0 & l_2 c_{\theta_2} \\ s_{\theta_2} & c_{\theta_2} & 0 & l_2 c_{\theta_2} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$A_3(\theta_3) = \begin{bmatrix} c_{\theta_3} & -s_{\theta_3} & 0 & l_3 c_{\theta_3} \\ s_{\theta_2} & c_{\theta_3} & 0 & l_3 c_{\theta_3} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

$$A_4(\theta_4) = \begin{bmatrix} c_{\theta_4} & 0 & s_{\theta_1} & l_4 c_{\theta_4} \\ s_{\theta_4} & 0 & -c_{\theta_1} & l_4 c_{\theta_4} \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

Where, H is homogeneous Transformation, T^0_n is transformation matrix from reference frame 0 to frame n, A_n is transformation matrix frame n, R^{n-1}_n is rotational matrix from reference frame n-1 to frame n, O^{n-1}_n is translation matrix from reference frame n-1 to frame n, $c_{\theta n}$ is cos (θn)1, $s_{\theta n}$ = sin (θn), l_n is Link length of coordinate frame n

3) Inverse kinematics

Inverse kinematics equation aims to determine possible combinations of the joint angle parameter with known link parameters in order to achieve the position of the desired end-effector. There are many novel kinematic solver methods based on analytical [14][15] or geometrical approach [16][17]. Analytical inverse kinematic solver for 4-DOF arm robot is presented by M. Amin [18]. In this study, kinematics is solved by using geometric approach with decoupling method especially defined for 4-DOF robot to simplify the calculation. This method separates the joint relationship of a robot in order to get the two links equation so it can be solved with simple geometry calculation. Then a separate link is reconnected to link base and gripper as a function of end-effector orientation or as a constant value. Figure 9 and Figure 10 show the illustrations of the inverse kinematic problem-solving using geometry calculations.

Table 1.
Servo angle range and set-point formulation

Joint	Angle range	Set-point formulation
Base	0°-180°	(-10 θ_1)+1500
Shoulder	0°-135°	(9.55556 θ_2)+630
Elbow	60°-180°	(-9.6667 θ_3)+2640
Wrist	0°-180°	(10 θ_4)+400
Gripper	60°-120°	(-9.3334 θ_5)+2340

θ_1 = base joint angle; θ_2 = shoulder joint angle; θ_3 = elbow joint angle; θ_4 = wrist joint angle; θ_5 = gripper joint angle

Table 2.
Robot model D-H parameter

Joint I	Joint angle (θ_i)	Twist angle (α_i)	Link length (a_i)	Link offset (d_i)
1	θ_1	-90°	0	l_1
2	θ_2	0°	l_2	0
3	θ_3	0°	l_3	0
4	θ_4	90°	l_4	0

θ_i = joint angle of coordinate frame-i; α_i = link turnover of coordinate frame-i; a_3 = link offset of coordinate frame-i; d_4 = link length of coordinate frame-i

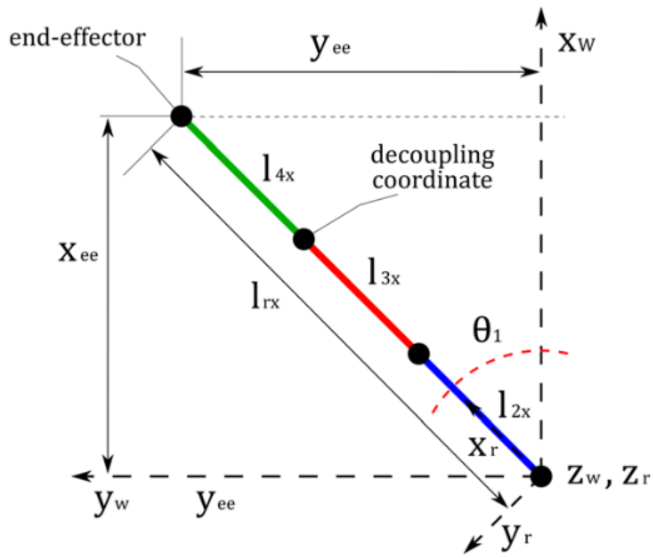


Figure 9. Illustration of kinematic solving (top view) (source: personal collection)

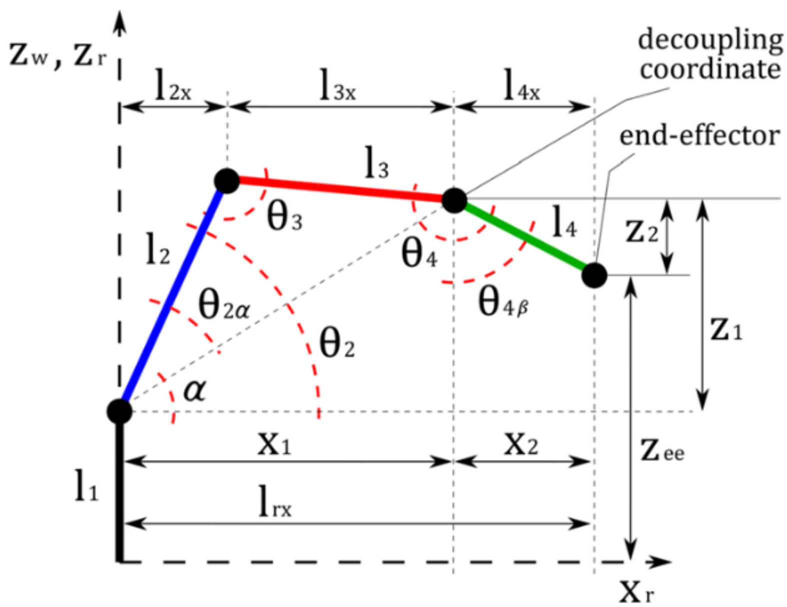


Figure 10. Illustration of kinematic solving (side view) (source: personal collection)

Shown in the graph above global coordinate or world coordinates xw, yw, and zw as basic references of equation, otherwise there are local coordinates or robot coordinates xr, yr, and zr. Input data for control system is end-effector coordinate which refers to world coordinate at x-axis noted as xee, at y axis noted as yee, and at z axis noted as zee. First step is to calculate θi. It can be easily defined because it has direct correlation to input data.

$$\theta_1 = \tan2^{-1}\left(\frac{y_{ee}}{x_{ee}}\right) \quad (8)$$

Then, l_{rx} can be defined since it also has direct correlation to input data. Notation l_{rx} is robot length viewed from above equal to resultant length at l_{rx} axis.

$$l_{rx} = \sqrt{{x_{ee}}^2 + {y_{ee}}^2} \quad (9)$$

Next step is to assume that link 3 and link 4 is decoupled. By determine the angle of $\theta_{4\beta}$ decoupling coordinate can be defined. Decoupling coordinate at x-axis and z-axis of robot coordinate is noted as x_1 and z_1. While decoupling coordinate is known, α angle can be calculated. Then the angle $\theta_{2\alpha}$ and θ_2 can be calculated by using law of cosine [5].

$$\alpha = \tan2^{-1}\left(\frac{z_1}{x_1}\right) \quad (10)$$

$$\theta_2 = \theta_{2\alpha} + \alpha \quad (11)$$

$$\theta_2 = \cos^{-1}\left(\frac{l_2^2 - l_1^2 - x_1^2 - z_1^2}{-2\, l_1^2 \sqrt{x_1^2 + z_1^2}}\right) + \tan^{-1}\left(\frac{z_1}{x_1}\right) \quad (12)$$

also, by using law of cosine, θ_3 can be calculated [5]

$$\theta_3 = \cos^{-1}\left(\frac{x_2^2 + z_1^2 - l_2^2 - l_1^2}{-2\, l_1 l_2}\right) \quad (13)$$

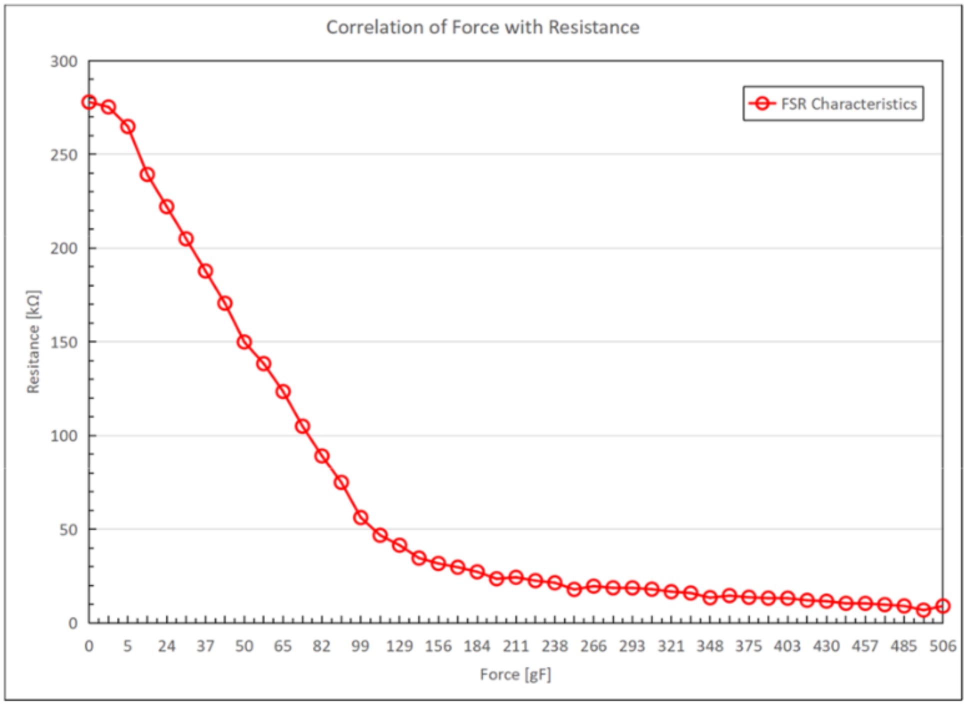


Figure 11. Force-to-resistance correlation graph

Last step is to determine the angle of frame 4 refer to frame 3, θ_4 by simple calculation below.

$$\theta_4 = (270 + \theta_{4\beta}) - \alpha - \theta_{2\alpha} - \theta_3 \quad (14)$$

4) Force control

a) Object physical characteristics

The objects that are used in the study have special characteristics to limit control problems. Object size is about 40 mm and has force resistant until 5 N. This means that the object will be shape-deformed when the force exceeds the value of 5 N which is equal to 509, 85 gF.

b) Force sensor

Sensors which are used to acquire forces value is FSR (force sensing resistor). In this study, the smallest type of FSR is used because it fit to the size of the robot model. FSR is a variable resistor that changes its resistance value based on the value of the forces that suppress it. The following graph in Figure 11 shows the correlation of the force and the FSR resistance value. When FSR doesn't get a compressive force then the resistance value is large, otherwise the greater the force that presses FSR, lower the resistance. This FSR characteristic make it suitable to become feedback sensor of force control system. The control system will acquire resistance value as representation of gripping force value received by the object.

III. Results and Discussions

A. Accuracy level

The accuracy of system to successfully estimate position and grip the object automatically is tested. The procedure starts with the object is put manually at origin position at OA coordinates (0, 0). Then the control system moves the robot to the position of the object. Error position from end effector of robot and the object in x-axis and in y-axis is obtained. Then the object is put manually within work area scope in x-axis direction as far as 40 pixels on the camera or equal to 13.33 mm and so on up to 640 pixels on a camera or equal to 213.33 mm in the work area. Furthermore, the object moves in the y-axis as far as 40 pixels on the camera or equal to 13.33 mm in the work area and repeat the testing procedure on the x axis. It is repeated until the final test at the maximum x-axis and maximum y-axis.

The obtained data resulted in Figure 12 shows the average absolute error in x-axis = 3.144 mm and the average absolute error in the y-axis = 3.798 mm. the percentage of error in the x-axis = 4.421 % and the percentage of error in the y-axis = 7.121 %. The system can estimate the position of object automatically from picture taken by camera with accuracy level in the x-axis = 95.578 %, while in the y-axis = 92.878 %. This result is quite good and prove that the system is successfully recognizes the object automatically using image processing.

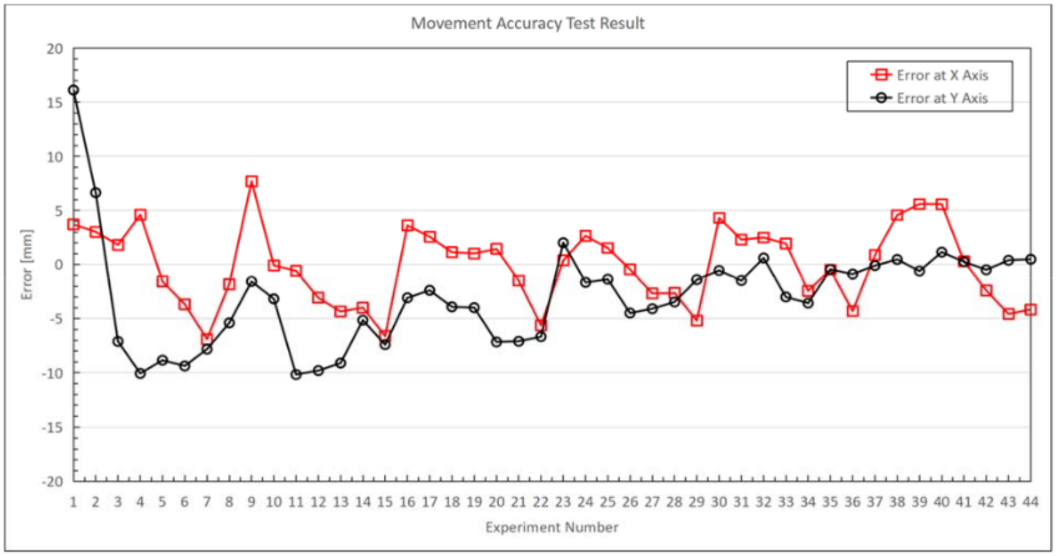


Figure 12. Results of movement accuracy test graph

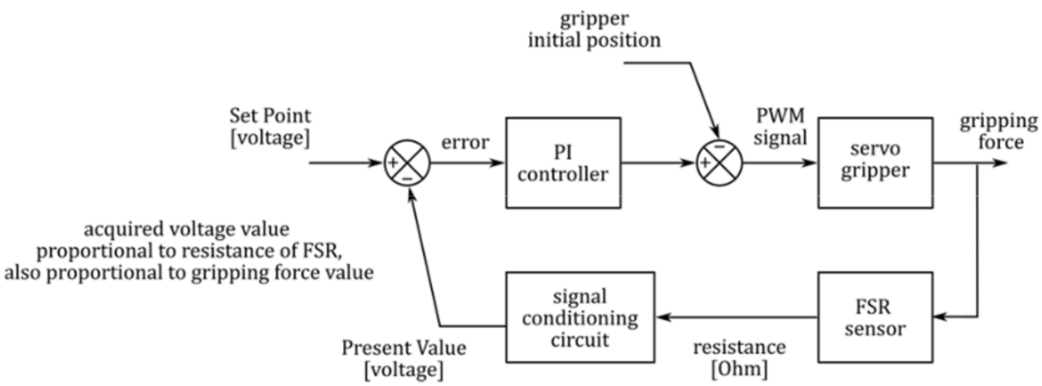


Figure 13. Block diagram of force control system (source: personal collection)

B. Gripping force control

Gripping force control used in the system is modified PI control method. The simple characteristic of the system which is usually called single input, single output (SISO), and a linear characteristic makes PI suitable for this system control as an alternative controller. The following Figure 13 is a block diagram of the gripping forces control.

As seen from the block diagram, the set-point and the input (feedback) of the system is voltage value that represents forces value. Set-point value is the limit of the object resistance against deformation. The difference that occurs between the set-point and input is an error value that will be processed by the PI controller to produce output which is the PWM value to control the gripper servo motor.

Figure 14. Testing object

The testing procedure starts by placing object precisely on the surface of the gripper and the center of the object interacts with the FSR sensor. The *Kp*, *Ti*, and *Td* parameters of control systems are set based on the trial tuning method. The testing of the activation effect to control system feedback is also executed. Tests performed on two different objects materials are shown in Figure 14. The first object is made of plastic material while the second object is made of polystyrene.

The graphs in Figure 15, Figure 16, and Figure 17 show values of gripping force acquired by sensor FSR while the robot is doing pick and place task to a plastic object. The picture shows a comparison when the force control system is activated to when it is deactivated. Figure 18, Figure 19, and Figure 20 show the values of gripping force acquired

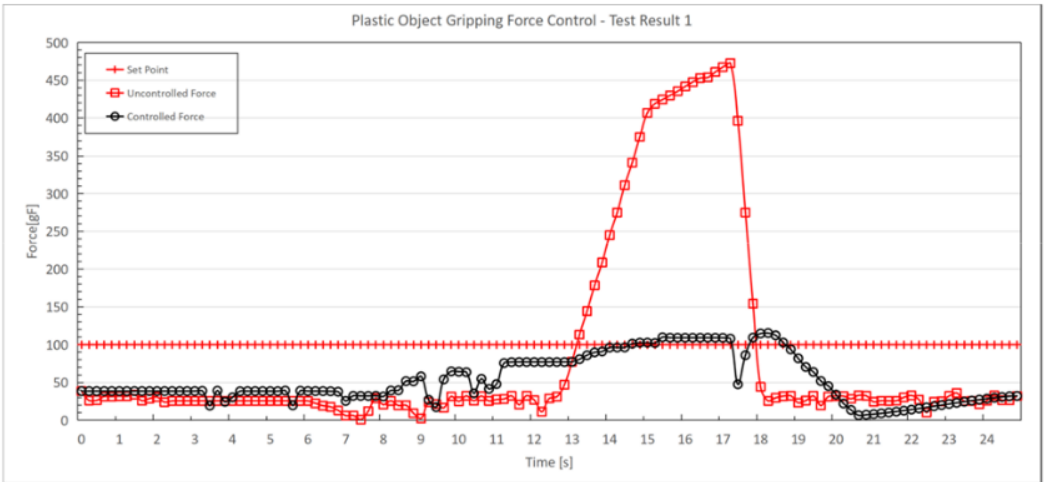


Figure 15. Results of gripping force control to plastic object with set-point 100 gF

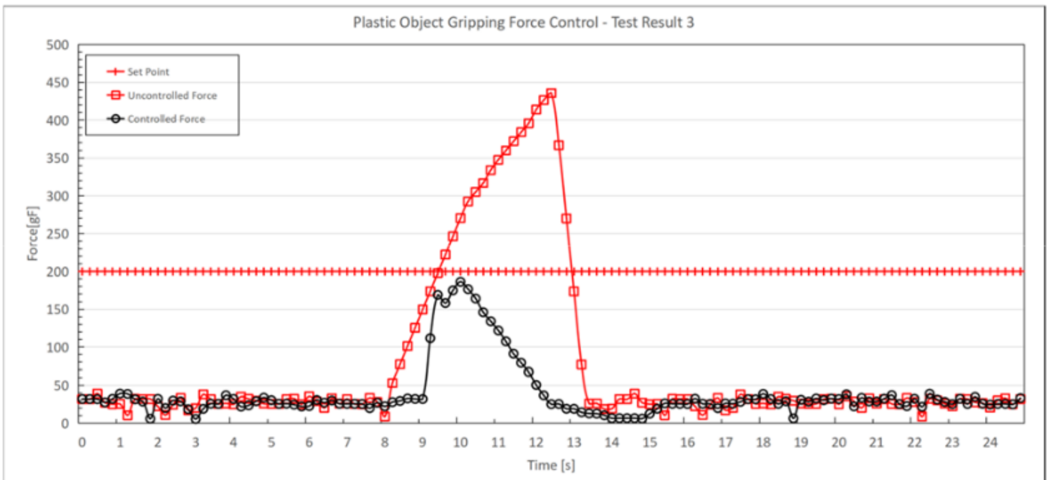


Figure 16. Results of gripping force control to plastic object with set-point 150 gF

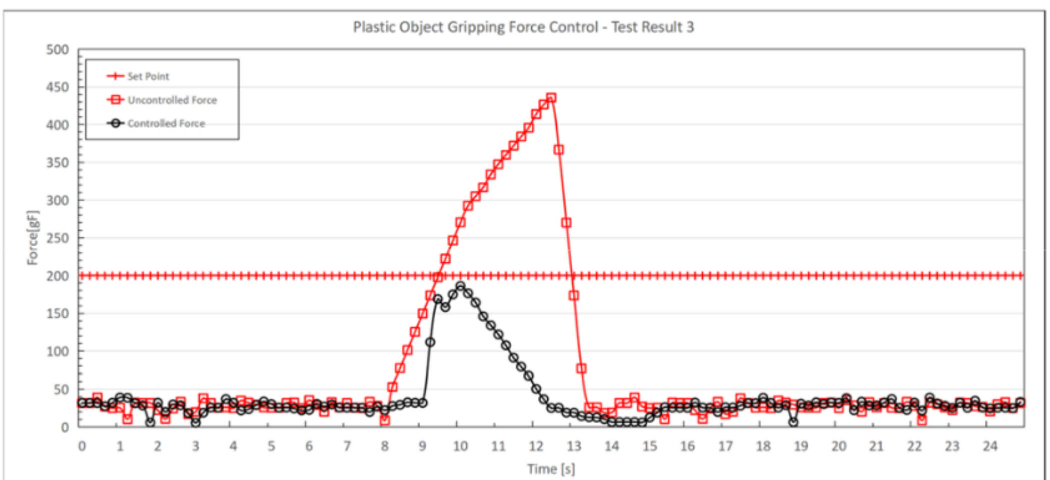


Figure 17. Results of gripping force control to plastic object with set-point 200 gF

while the robot is doing pick and place task to a polystyrene object. When gripping force controller is not activated, the error rises with overshoot value exceeds 100 %. That means the gripping process potentially damage the object and the robot itself. When the force control is activated, the generated force properly controlled. Force value oscillates

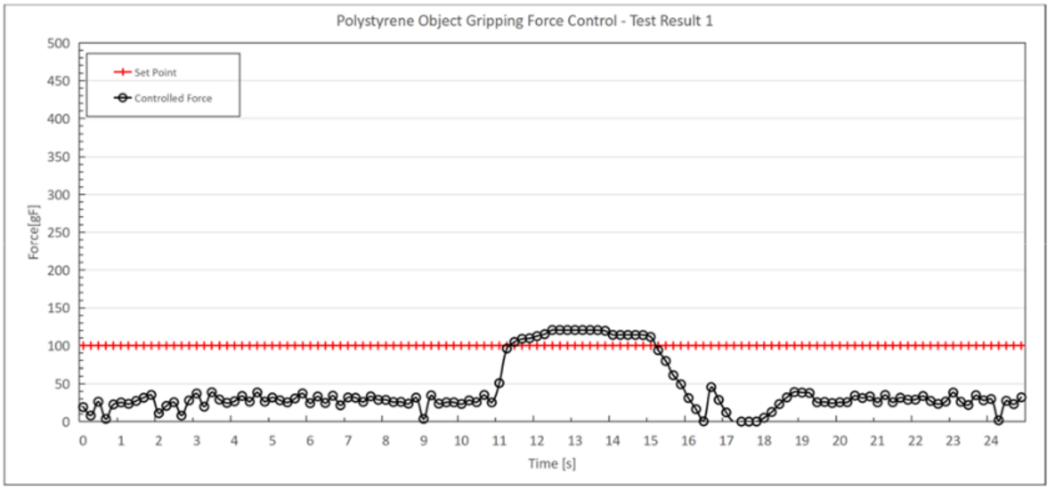


Figure 18. Results of gripping force control to polystyrene object with set-point 100 gF

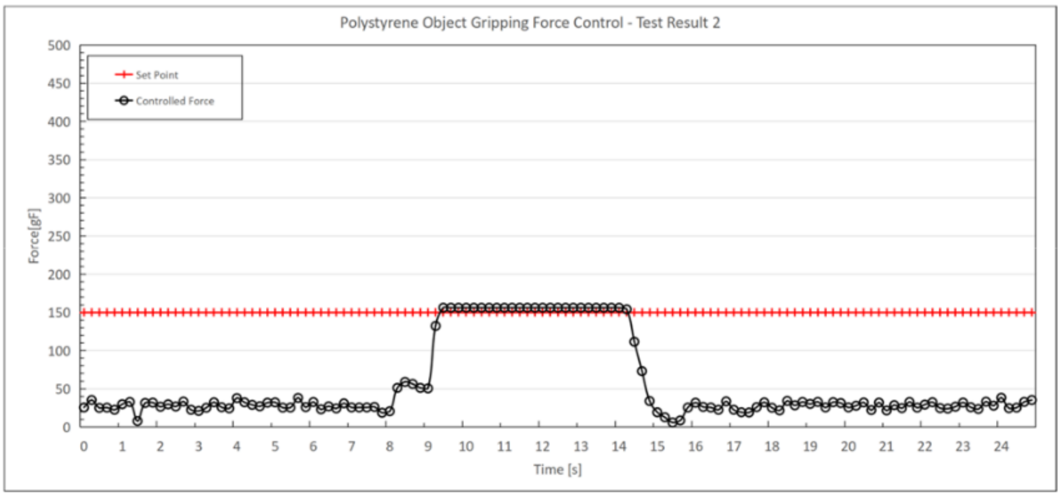


Figure 19. Results of gripping force control to polystyrene object with set-point 150 gF

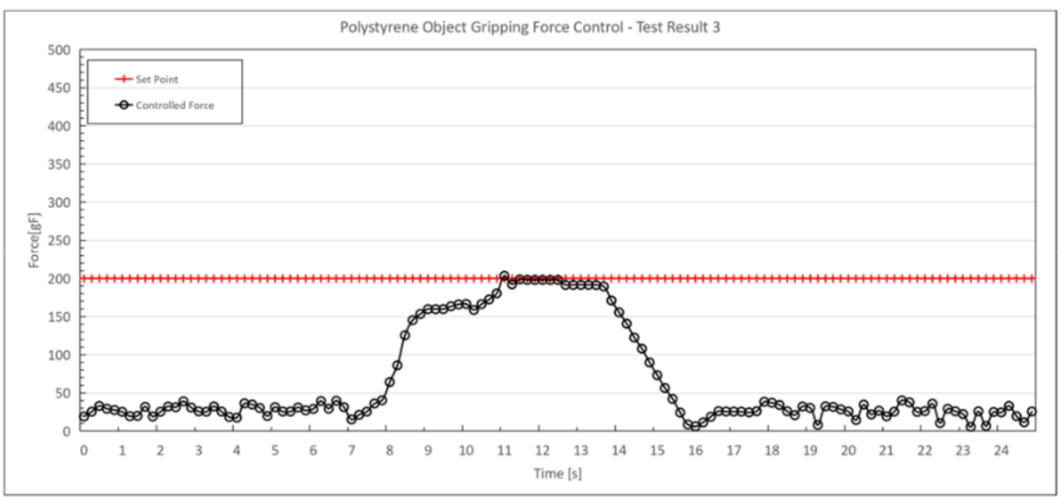


Figure 20. Results of gripping force control to polystyrene object with set-point 200 gF

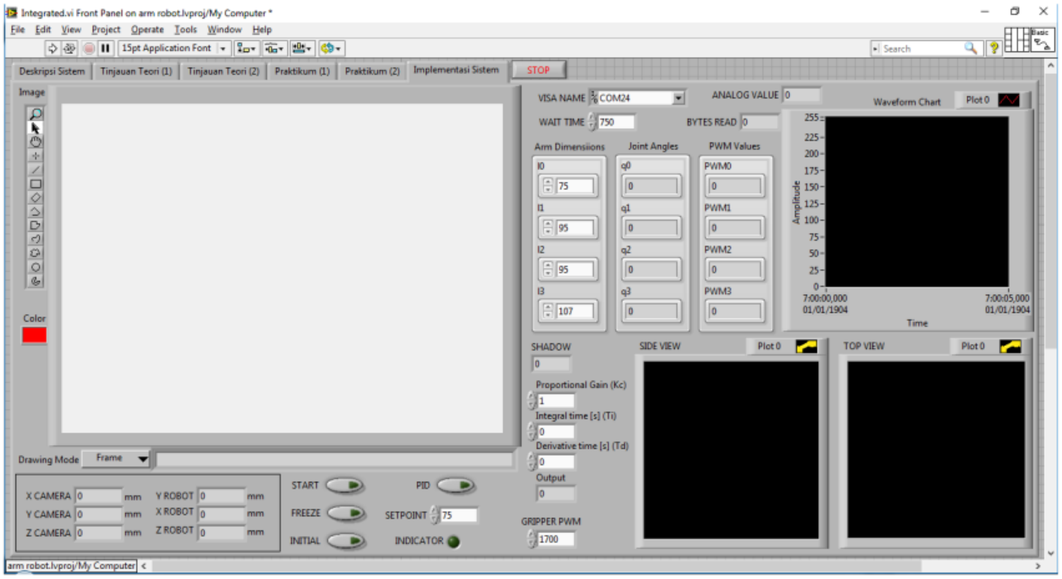


Figure 21. Implementation of integrated system

around the set-point with overshoot error <10 %. Even with the different objects and the different set-point values, the system is able to control the generated forces during gripping process to ensure that gripping process will not damage the object or the robot itself.

C. LabVIEW program interfaces

In order to make the system control easily understood, it is designed with informative visualization to help user learns and understands robotic control concept deeply. The program interface consists of several display of each sub-system and the implementation of an integrated system as shown in the Figure 21 below. Before the user does the experiment and implementation on the integrated system, the user is introduced to a general description of the system and a brief overview of the theory related to the system.

IV. Conclusion

Arm robot models can represent an industrial scale arm robot, because they have the same degrees of freedom and kinematics parameter despite having different dimensions the actuator's specifications. This study's result is a control system which can automatically estimate the object position using image processing and can apply to industrial scale arm robot. The robot control system in objects tracking is highly accurate, the test results show the average absolute error in the x-axis = 3.144 mm and the average absolute error in the y-axis = 3.798 mm. the percentage of error in the x-axis = 4.421 % and in the y-axis = 7.121 %, It means the accuracy level of the system in the x-axis = 95.578 %, while in the y-axis = 92.878 %. This result is quite good and prove that the system is successfully recognizes the object automatically using image processing. The modified PI control system is suitable for controlling gripping forces. The system generates a response with overshoot value <10 % to prevent shape deformation and damage to the gripped object.

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