OptimizationOf Straight Movement 6 Dof Robot Arm With Genetic Algorithm

R. Suryoto Edy Raharjo
JTETI, Faculty of Engineering
UGM, Indonesia

Oyas Wahyunggoro
JTETI, Faculty of Engineering
UGM, Indonesia

Priyatmadi
JTETI, Faculty of Engineering
UGM, Indonesia

***Abstract*—This paper proposes a genetic algorithm (GA) to optimize the straight movement of the robot arm for 6 DOF. The objective function of the GA is proposed to find the optimal values of the movement of the robot arm in a straight line trajectory. As more and more levels of Degree of Freedom (DoF), the more difficult to achieve precision, especially during straight motion from the starting point (initial point) to the point of destination (final point), which is affected by the determination of the swivel angle of each actuator, the linearity of the trajectory length straight-effector motion, and the number of Intermediate Point required. Forward kinematics is used to find the coordinates of the end effector, and a linear function of a straight line from the starting point (initial point) to the point of destination (final point) is used as the objective function of GA.**

Keywords—6 DOF arm robot; arm robot; genetic algorithms.

I. Introduction

The robot is a machine that can be directed to do a variety of tasks to assist the task of the human being. In its application in the industrial world, the robot arm is used to move goods from one place to another either automatically or manually. Doing the same job over and over again and in a long time [1].Degrees of freedom (DoF) on the robot arm is a linear or rotary motion on an axis (axis). Precision robotic arm obviously affects the success of the work. The more levels Degree of Freedom (DoF), the more difficult to achieve precision [2], especially when the straight motion.

In the study by SrinivasanAlavandar, AdhivairavaSundaram and Nigam [3 they use GA to control the robot arm as a masseuse , with input sensor cameras, encoders at each joint and switch on the grip. GA is also used to optimize the movement of the robot arm , so that the energy consumption to a minimum, accelerating the movement from one point to another, while avoiding collisions with surrounding objects [4].

KazemBahaaIbraheem, Ali Mahdi Ibrahim, and Ali TalibOudah [5], using GA to optimize the trajectory of 3 DOF robotic arm . Minimize the distance and travel time, without exceeding the maximum torque and keep from colliding with objects around it. Quadrinomial and quintic polynomial are used to determine the point of beginning, middle and end points, so that the trajectory of a curved path, not a straight line.

In this paper, the proposed trajectory planning of point-to-point based method adopts GA which forward kinematics is used to find the coordinates of the end effector, and a linear function of a straight line from the starting point (initial point) to the point of destination (final point) is used as the objective function in GA.

The system used to control a robot, receipts software, hardware and Robot Arm. Where the feedback from the robot arm angle the form of data each servo. With the configuration shown in Fig. 1, the system is easier to be modified, can use various types of algorithms in software without changing the hardware and less costly.

II. System Design

In this research, the robot arm using a digital servo motors Dynamixel AX-12A, Fig. 1, which is equipped with angular position output. While the software for the controller and servo data recorder, created using Visual Studio 2010, as shown in Fig. 3. In software, will be included angle of each servo at the start point and end point, and will record the angle of each servo while the movement from the start point to the end point. Data corner of each servo, taken at intervals of 100ms, and the result is the data in the spreadsheet file xlsx format.

III. Kinematics Analysis

Forward kinematics is used to obtain the coordinates of the end effector, with the input of the angle of each servo. Starting with a robotic arm frame assingment to Fig. 4, further modeling with DH parameters as in Table 1 [6]. Due to changes in the angle servo 6 (wrist) did not affect the end effector coordinates, then the calculation is used only in length (a_6) alone. In the calculation of the matrix, the notation will be used to shorten the calculation, among others:

$$C_i = \cos\theta_i$$

$$S_i = \sin\theta_i$$

$$C_{ij} = \cos(\theta_i + \theta_j)$$

$$S_{ij} = \sin(\theta_i + \theta_j)$$

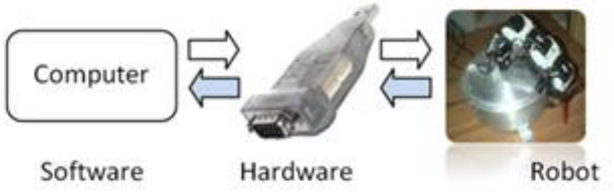

Fig. 1. Control of Robot Arm

Fig. 2. Robot Arm 6 DoF

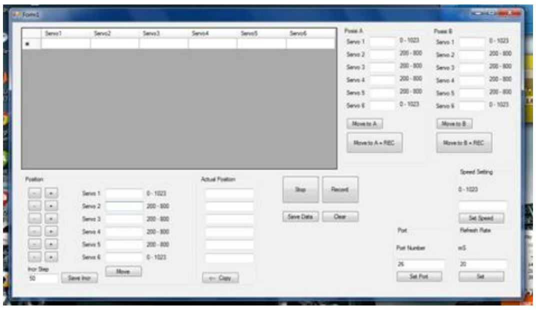

Fig. 3. Software Controller and Recorder

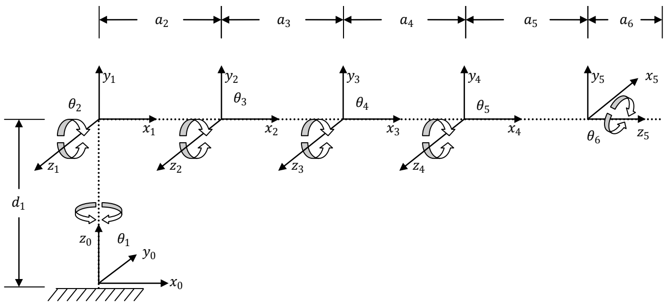

Fig. 4. Frame Assignment

TABLE I. DH TABLE

Joint *i*	α_i	a_i	d_i	θ_i
1	90	0	d_1	θ_1
2	0	a_2	0	θ_2
3	0	a_3	0	θ_3
4	0	a_4	0	θ_4
5	0	$a_5 + a_6$	0	θ_5

Based on Table I, the transformation matrix is obtained for each of the joints, as follows:

$$T_1^0 = \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

$$T_2^1 = \begin{bmatrix} C_2 & -S_2 & 0 & a_2C_2 \\ S_2 & C_2 & 0 & a_2S_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

$$T_3^2 = \begin{bmatrix} C_3 & -S_3 & 0 & a_3C_3 \\ S_3 & C_3 & 0 & a_3S_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

$$T_4^3 = \begin{bmatrix} C_4 & -S_4 & 0 & a_4C_4 \\ S_4 & C_4 & 0 & a_4S_4 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

$$T_5^4 = \begin{bmatrix} C_5 & -S_5 & 0 & (a_5 + a_6)C_5 \\ S_5 & C_5 & 0 & (a_5 + a_6)S_5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$T_5^0 = T_1^0 T_2^1 T_3^2 T_4^3 T_5^4$$

$$T_5^0 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & p_x \\ r_{21} & r_{22} & r_{23} & p_y \\ r_{31} & r_{32} & r_{33} & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

From the calculation, the matrix equation obtained robotic arm is:

$$r_{11} = C_1C_{23}C_{45} - C_1S_{23}S_{45} \quad (7)$$

$$r_{12} = -C_1S_{23}C_{45} - C_1C_{23}S_{45} \quad (8)$$

$$r_{13} = S_1 \quad (9)$$

$$P_x = C_1(a_2C_2 + a_3C_{23}) + C_1C_{23}(a_4C_4 + (a_5 + a_6)C_{45}) \quad (10)$$

$$r_{21} = S_1C_{23}C_{45} - S_1S_{23}S_{45} \quad (11)$$

$$r_{22} = -S_1S_{23}C_{45} - S_1C_{23}S_{45} \quad (12)$$

$$r_{23} = -C_1 \quad (13)$$

$$P_y = S_1(a_2C_2 - a_3C_{23}) + S_1C_{23}(a_4C_4 + (a_5 + a_6)C_{45} - S_1S_{23}(a_4S_4 + (a_5 + a_6)S_{45} \quad (14)$$

$$r_{31} = S_{23}C_{45} + C_{23}S_{45} \quad (15)$$

$$r_{32} = C_{23}C_{45} - S_{23}S_{45} \quad (16)$$

$$r_{33} = 0 \quad (17)$$

$$P_z = d_1 + S_{23}(a_4C_4 + (a_5 + a_6)C_{45}) + C_{23}(a_4S_4 + (a_5 + a_6)S_{45}) + a_2S_2 + a_3S_{23} \quad (18)$$

IV. GENETIC ALGORITHMS

Genetic algorithms, first introduced by David Goldberg, an idea which the cycle can be seen in Fig. 5. The cycle is then corrected by ZbigniewMichalewics by adding elitism operator and reverse the process of selection after reproduction process [7]. Overview of genetic algorithms cycle that has been refurbished by ZbigniewMichalewics, can be seen in Fig. 6. In this study, the authors apply the GA to the cycle that has been updated as in Fig. 6.

Objective function in GA, a deviation of the average value of the coordinates of the effector functions of linear straight line from the starting point to the end point in the dimension of space,which is expressed by Eq. (19) and (20)in a single individual.

$$f_{(x_i)} = \frac{|(P_i - A) \times (P_i - B)|}{|B - A|} \quad (19)$$

$$\sum_{i=1}^{n} \frac{f_{(x_i)}}{n} \quad (20)$$

A. Initial Population

Initial population, is a collection of individuals in the form of end effector coordinate data experimental results. In this study a collection of individuals when the end effector coordinate movement from the starting point to the end point, as in Fig. 7. So genes in individuals is one of the coordinates of the end effector at the time of data collection. So as to form the initial population takes a few tries, Fig. 8

B. Crossover and Mutation

The method used for the crossover, which is a one-cut point. Where we choose at random one chromosome and swap genes from the cut-point position with another chromosome. First, we determine the value of the crossover probability Pc with a value of 0-1. Followed by generating a random number R between 0-1, as the number of chromosomes. If $R_{[i]}$<Pc, then *i* chromosome will be selected as a parent. The position of the cut-point, we find that either generate random numbers between 1-chromosome length (number of genes in a single chromosome). Suppose the cut-point = 3, then:

$$[1\ 2\ 3\ 4\ 5\ 6] \leftrightarrow [ABCDEF]$$

$$offspring_{[i]} = [1\ 2\ CDEF]$$

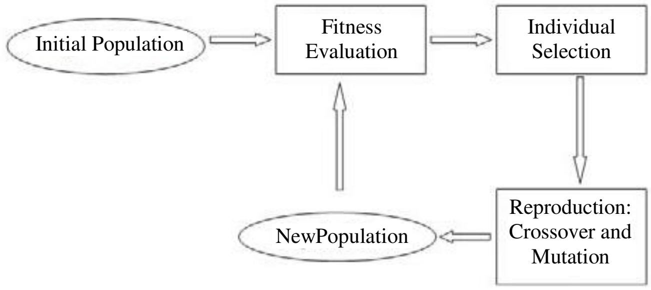

Fig. 5. Genetic Algorithms cycle by David Goldberg.

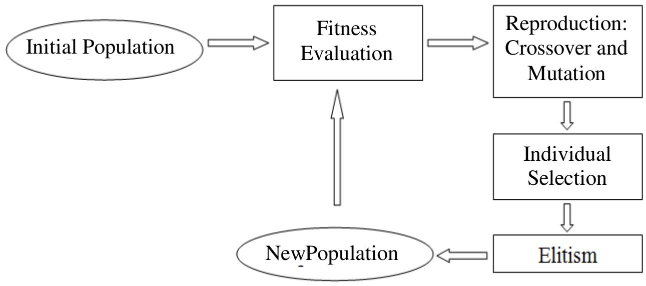

Fig. 6. Genetic Algorithms cycle that has been refurbished by Zbigniew Michalewics

Mutation process, starting with determining mutation rate Pm which is the percentage of the number of genes to be mutated in the population. It starts by looking for gene length, the number of genes in the population, ie the number of genes in the x chromosome population. Subsequently generate random numbers between 1-length genes, gene length x Pm then selected genes to be transferred, will be changed.

C. Selection

Fitness evaluation is done by selecting individuals, where each individual will be searched and compared with the value of the objective value of the objective population. Individual selection methods roulette machines, where each individual will receive a probability value reprodukasi random manner, the individual results are a collection of individuals with the highest probability value.

The selection process using the roulette machine. Each individual sought probability value $P_{[i]}$, and the cumulative probability value $C_{[i]}$ with the formula:

$$P_{[i]} = \frac{fitness\ value}{total\ fitness\ population} \quad (21)$$

$$C_{[i]} = P_{[1]} + \cdots + P_{[i]} \quad (22)$$

D. Elitism

The selection of chromosomes that will be included in the elite list by using the value of the objective function and fitness value. If the value is greater than the Threshold elitism, the chromosomes are included in the elite group.

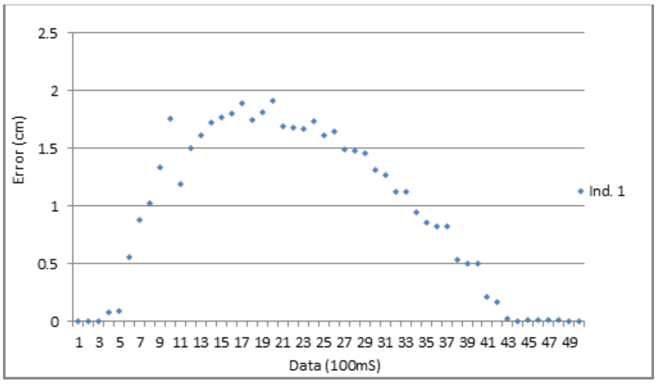

Fig. 7. Individu

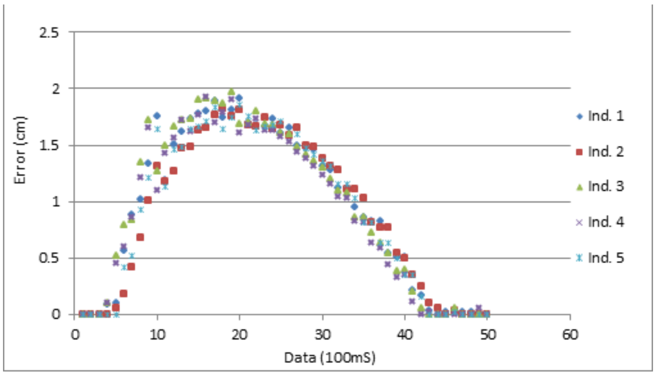

Fig. 8. Initial Population

V. RESULTS

In this study, carried out data collection 5 times in one experiment, and 3 types of experiments, namely:

- Experiment 1
  Starting point to the end point without any intermediate point, Fig. 9.
- Experiment 2
  Starting point to the end point with 1 intermediate point, Fig. 10.
- Experiment 3
  Starting point to the end point with 2 intermediate point, Fig. 11.

Starting point and end point have the same value for all experiments.

GA optimization results for each trial, when compared as in Fig. 12 and Table II. Absolute error value is the value of the error, and the data collection interval is 100ms.

VI. CONCLUSIONS

GA method can be used to find the most optimal values of the experimental data, instead of just looking for the best value for a function.

From the experimental results, the maximum error value and the average value is the highest error experiment 1 (without intermediate point), while the lowest was 3 trial results. Could be concluded that, the more Intermediate Point in the trajectory, will decrease the value of error, so it can approach trajectory desired. However, a growing number of Intermediate Point, will increase the time it takes to move.

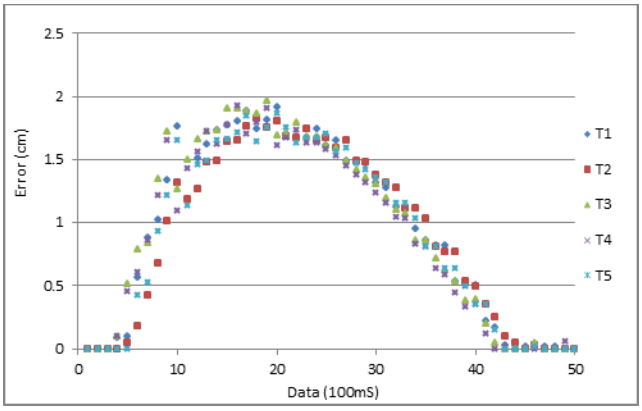

Fig. 9. Experiment 1

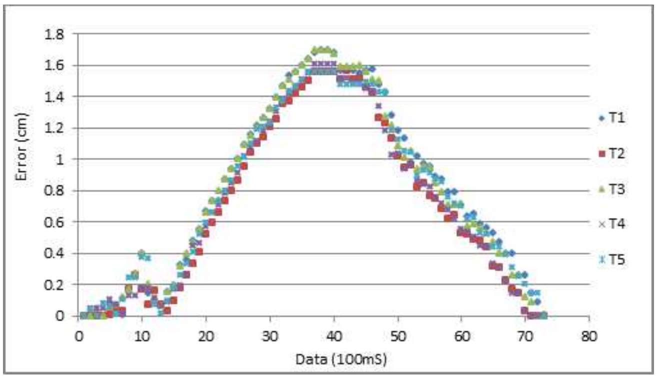

Fig. 10. Experiment2

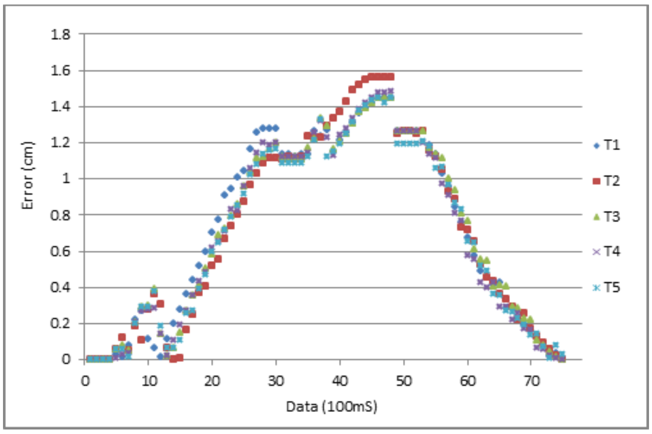

Fig. 11. Experiment3

TABLE II. RESULTS OF COMPARISON

Experiment	Max. Error (cm)	Time (mS)	Mean Error (cm)
1	1.951644	5,000	1.01499
2	1.652173	7,700	0.742501
3	1.469483	7,800	0.700036

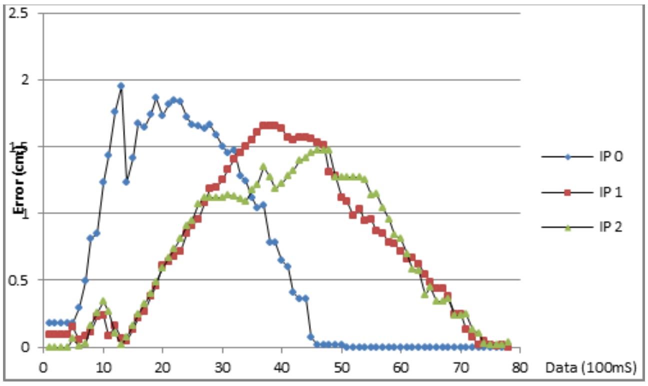

Fig. 12. Comparison of Experiments

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