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遺伝的アルゴリズムを用いた柔軟ロボットアームの制御

Control of Flexible Arm Robot Using Genetic Algorithm

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CONTROL OF FLEXIBLE ARM ROBOT USING GENETIC ALGORITHM

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ABSTRACT

This paper describes the control of a flexible arm robot using genetic algorithm (GA). GA simulates the general process of the natural evolutions and GA has been applied to many of analyses of the mixed mathematical problems and the engineering problems. It is very difficult to solve the inverse kinematics of the flexible arm robot. We try to apply the GA technique to analyzing the inverse kinematics of the flexible arm robots. The flexible arm of the robot is divided into small parts and the robot becomes a many degrees of freedom robot. The proposed method is applied to the great many degrees of freedom robots and the effectiveness of the method is shown.

1. INTRODUCTION

Many flexible arm robots are used and will be used in space development, atomic power plant and so forth. The arm and gripper of the such robot must be positioned at the fixed position accurately. It is very difficult to analyze the inverse kinematics of the flexible arm robot in order to position the robot arm for the planned workings.

The genetic algorithm (GA) works have emerged as promising solutions to the problems of exploration and optimization. The GA approaches have allowed not only solving complicated linear problems but also solving non–linear troublesome problems. Many of the works using GA technique have been done in a few years. GA is a search algorithm based on the mechanics of natural genetics and natural selections. GA has been developed by J.Holland and it has been treated by experience and by trial and error. The primary work of GA is performed in three routines of select, crossover, and mutation. The combination of these three routines is used for analyzing the problems as a general rule.

We try to apply GA technique to the positioning problem of the flexible arm robot. The arm of the robot is divided into many small parts and the robot becomes a multi–degrees of freedom robot. We replace the inverse kinematics of the flexible arm robot with the inverse kinematics of the articulated robot. The replaced articulated robot has many degrees of freedom. The robot has extraordinary degrees of freedom in general.

This paper describes the control of a flexible arm robot using genetic algorithm. The flexible arm is divided into many small arms. Each of the arms is formed of an actuator and a joint and they are connected successively. We apply the GA technique to the control of these succesive small arms and we can get the solusion of the inverse kinematics of the flexible arm.

For example of the flexible arm positioning, we show the contol of twenty degrees of freedom robot and show the effectiveness of the proposed method. The proposed method can be applied to solving the various kinds of flexible arm robot and moreover to solving the problems of the flexible structures.

2. INVERSE KINEMATICS OF ROBOT

2.1 GA coding

Mapping from the problematic space of solving problem to GA string of gene is called a GA coding. Figure 1 shows N degrees of freedom articulated robot. Figure 2 shows the coding of the above robot. Each angle of the joint is ϕ_i and each angle is expressed as m bits.

According to the above mentioned coding method, N degrees of freedom robot is exprecsed by (N X m) bits. Each individual of GA is formed of (N X m) bits string.

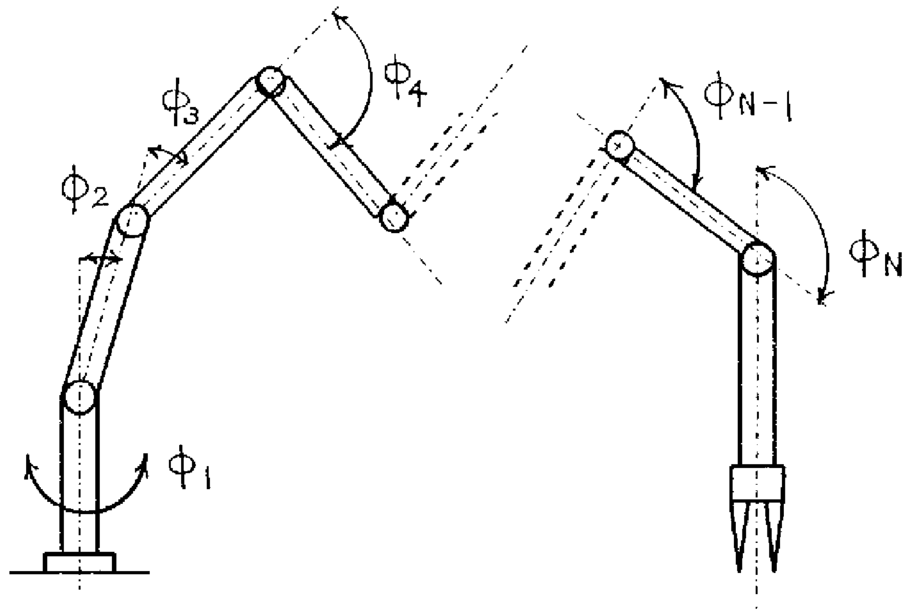
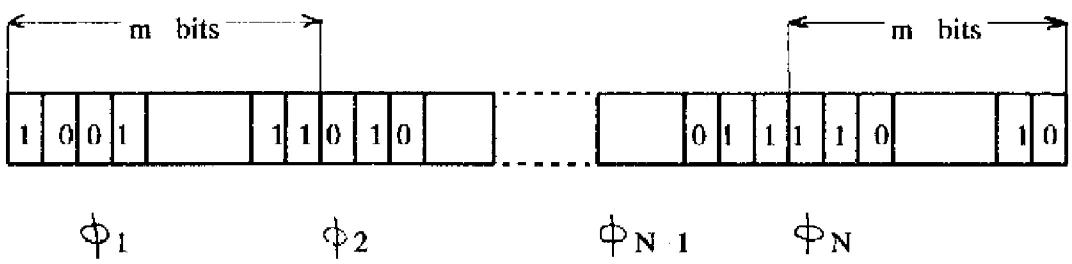


Fig.1 N degrees of freedom robot



total bits = N X m (bits)

Fig.2 GA Coding of articulated robot

2.2 Method of solving the kinematics of robot

We try to solve the robot motion. The optimum solution of the kinematics of the robot is found among the candidates of the solutions. The optimum solution is the solution that maxmize or minimize a performance function or the evaluation function. The performance function or the evaluation function is used in GA technique. They are used for evaluating the adaptability of each solutions. The optimum solution is explored among the working solutions as the follo-wing approach and the flow of the GA operation is shown in Figure 3.

[steps of caluculation]:

(step 1): The zeroth individuals are formed at random. This is the initial group and the ini-tial group is consisted of S individuals. The number of S is chosen by experience.

(step 2): The adaptability of each individuals is calculated using the performance function and they are listed in tne order of each performance value.

(step 3): Some individuals are selected and remain. Others are eliminated. The probability of the selection is calculated in order of the adaptability list.

(step 4): Two individuals are selected according to the selection probability. The operation of crossover is carried out. The selected individuals are parents and the new child-ren are born by the crossover of the parents.

(step 5): The operation of mutation is carried out to some individuals of some generation.

(step 6): Q Pieces of the individuals are listed in the order of the adaptability. The infe-rior individuals 10 % of the generation are taken off and new individuals are taken in. The new individuals are produced at random. The operation of replacing the old and inferior individuals by the new individuals. This operation is the artificial selection that was proposed by our last study.

(step 7): If one of the individuals filfills the end condition, the calculation is ended. If not, the above steps from the step 2 to the step 6 are repeated.

The step 6 is the artificial selection and it is a activation.

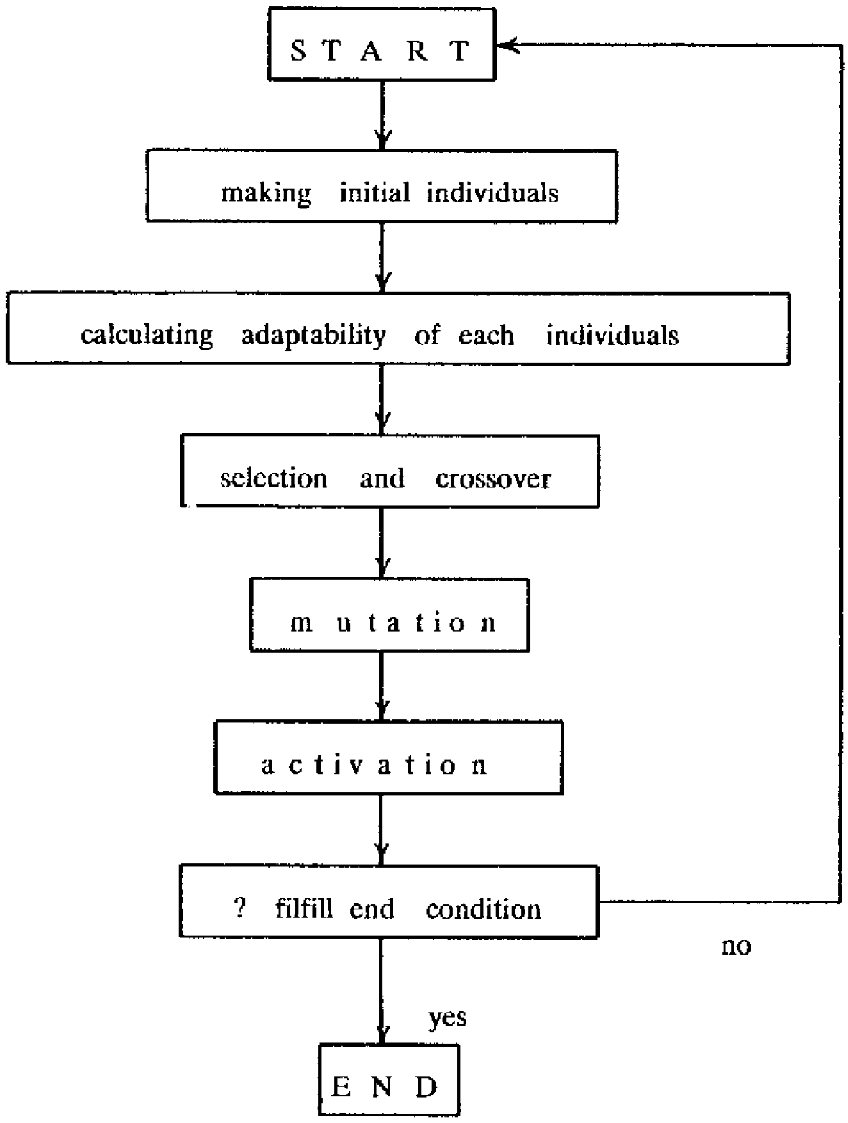


Fig. 3 flow of GA operation

3. INVERSE KINEMATICS OF TWENTY DEGREES OF FREEDOM ROBOT

3.1 Coding of the robot

We try to set a gene up to the robot that has many joints. In this study eight bits of the gene are matched with each joints. Each eight bits of the gene is chosen at random at the zeroth generation of GA. Figure 4 shows the coding of the each joints of the robot. The new gene of the next generation is determined by the change from the angle of the current generation. The next angle ϕj is expressed by the cahnge of the angle between ϕj and the current angle ϕi and ϕi;

$$\phi j = \phi i + \text{change of angle } (\phi j - \phi i) \qquad (1)$$

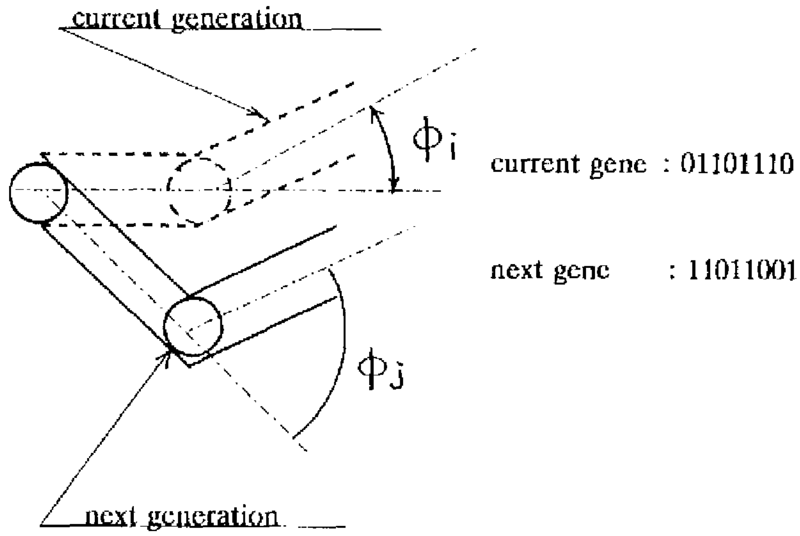


Fig. 4 coding of joint angle (8 bits gene)

3.2 Determination of various parameters

The various parameters that are used in GA operation are determined as follows:

(1) Growth of initial group; twenty individuals are grown and their genes are determined at random. Each genes is expressed as binary eight bits.

(2) Caluculating the adaptability of each individuals; next equation is the performance function and if this value is smaller, the adaptability of the individual becomes higher.

$$\text{adaptability} = (X - X^*) \qquad (2)$$

X is the current position of robot hand and X^* is the target position of robot hand.

(3) Crossover; one point crossover is used.

(4) Mutation; one point mutation is used. One bit among eight bits is changed. Binary bit 1 is changed to bit 0 or in a reverse order.

(5) End condition; if the robot hand reaches to the target position, then calculation is end and if not, thousandth generation is end condition of caluculation.

3.3 Results of experiment

Twenty degrees of freedom robot avoids some obstacles and reaches to the target. Figure 5 shows the executive screens of the experiment. The robot arm starts from the left corner of the screen and begins to avoid the obatacles. The robot arm moves about all over the screen and aims at reaching to the destination. The target is located at the upper right corner of the screen. The obstacles are arranged at random.

All the tries of experimental exploration do not succeed and some trials fail. Sometimes the robot arm can reach to the target and can not reach to the objective in some cases. Figure 6 shows the avarage generations of the successful trials. The value versus each numbers of the obstacles means the avarage of 50 trials. From 600 to 700 generations the robot arm gets to the target and the robot gripper can grip a part or can transfer a part from the start point to the goal point. Figure 7 shows the successful ratio of the trials. The more the obatacles increase, the worse the ratio of the successful trials is. The value is the average of 100 trials. In the case of the 40 obstacles, the successful ratio becomes near ten percent.

As above mentioned experiment it is easy to get the solution for the inverse kinematics of an articulated robot. It is very difficult to get analytically the solution of the robot that has extra freedom. We get the solution easily using GA operation. The obtained solutionis not the optimum solution always but it is a practical solution. We can get a solution for motion of a flexible arm robot.

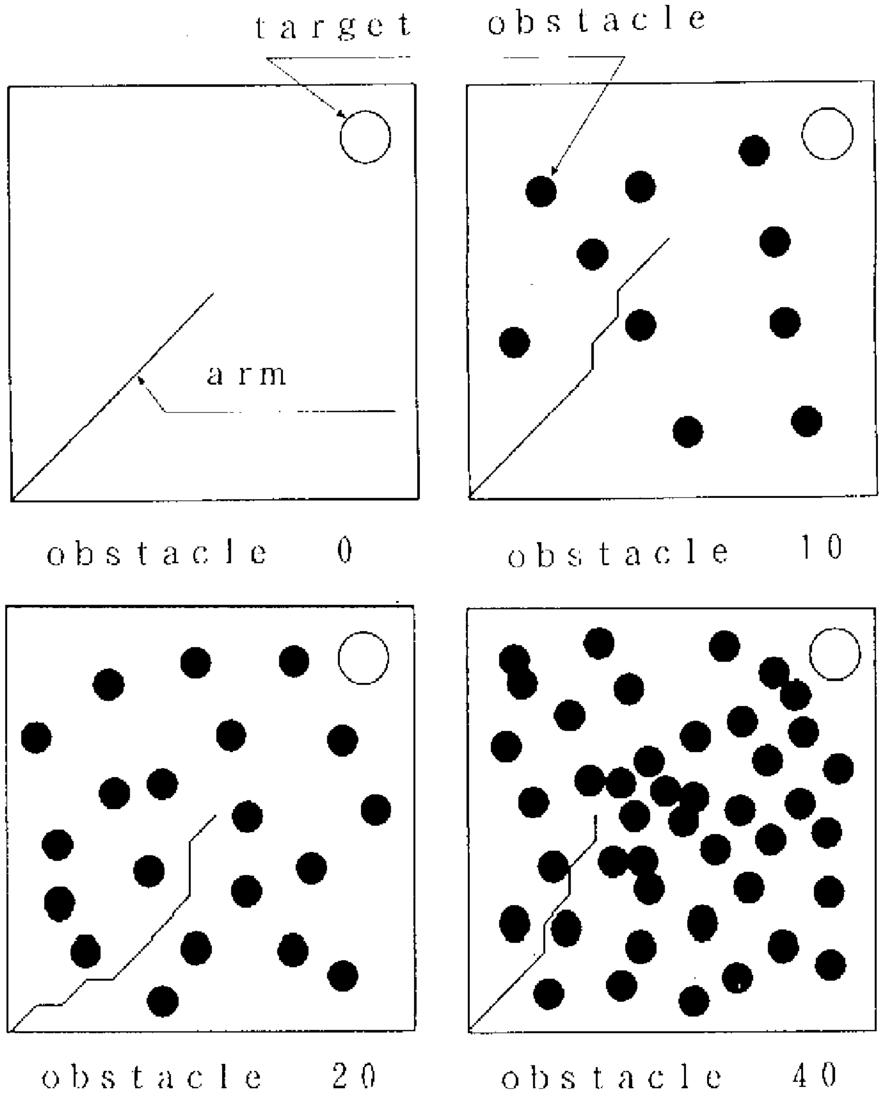


Fig. 5 Executive screens of experiment

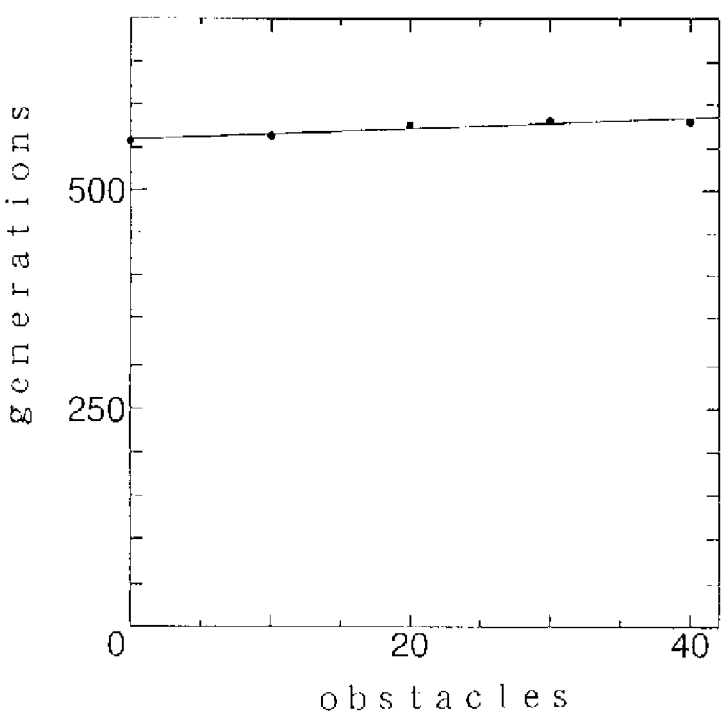


Fig.6 Numbers of obstacles versus generatrions

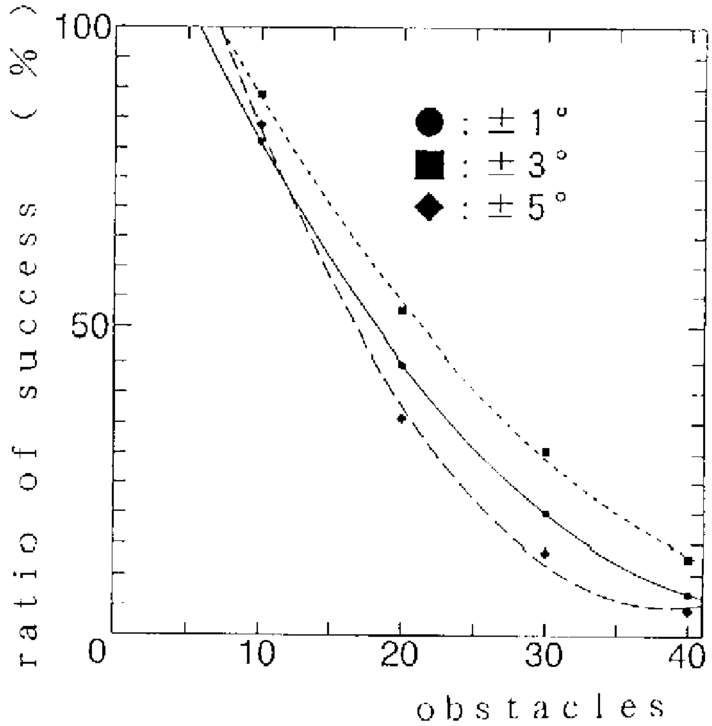


Fig.7 Ratio of succeed versus obstacles

4. ANALYSIS OF FLEXIBLE ARM

We can control the flexible arm robots using the above mentioned method. The flexible arm is devided into many small elements and the flexible arm robot is replaced with the articulated robot that has N degrees of freedom (Figure 8). Then we can control the robot using GA technique. It is treated by trial and error that how many elements the flexible arm is devided into.

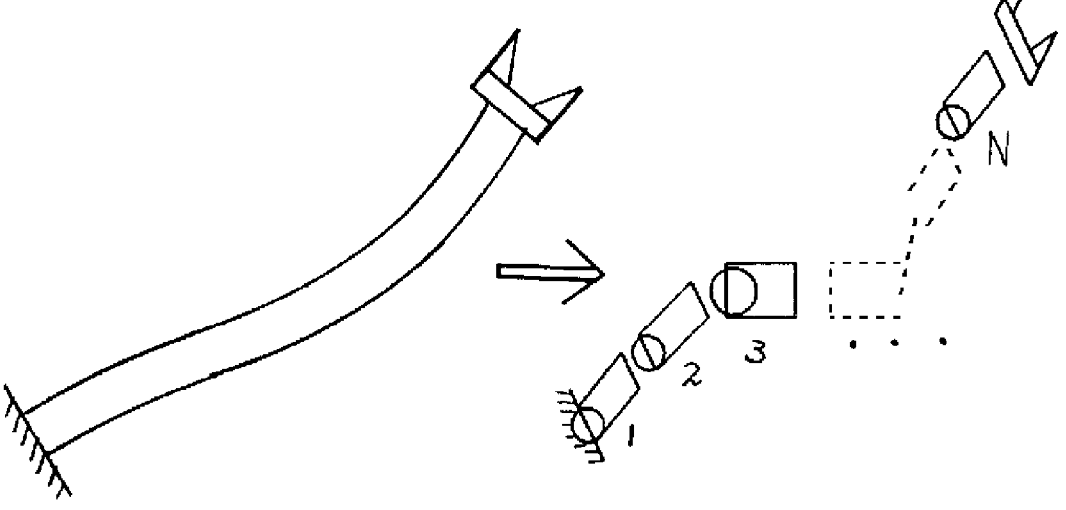


Fig.8 Replacement of flexible arm robot with articulated robot

5. CONCLUSION

The control method oa a flexible arm robot sing genetic algorithm (GA) was proposed. In the first half of this paper the method for analyzing the inverse œinematics of an articulated robot was resented. In the last half part the proposed method was tried to apply the flexible arm robot. The flexible arm was divided into small part and the robot became the multi–degrees of freedom robot. We tried to apply the method to a extraordinary degrees of freedom robot and concretely we solved the inverse kinematics of twenty degrees of freedom robot.

If this method is extended moreover and is improved further the proposed method can be applied not only to a flexible arm robot but also to a flexible structure.

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