FINDING THE BEST GRASPING POINT IN OBJECT MANIPULATION TASKS

A Comparison between GA and PSO Methods

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Abstract: Grasp planning is one of the most interesting subjects of object manipulation tasks in robotics and the development of grasp methods would be affected the robot performance. One of the most important subjects which is discussed in grasp planning, especially in industrial applications, is optimal grasp planning and finding the best grasping point. So it is important to find the best grasping point that the manipulator contact with object. In this paper, the MAG performance index, which is designed for object manipulation tasks, would be used for two different types of objects which are manipulated in the predefined path. Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) methods would be used to maximize this index and find the best grasping point and finally compared with each other. The results show that in faster object manipulation tasks, the GA method is more suitable than PSO method. Since in accurate object manipulation tasks, the PSO method is preferred to GA method.

1 INTRODUCTION

Object manipulation is defined as the translation or change in objects orientation by robot manipulators. For a translation task, robot manipulator moves a body by exerting appropriate joint forces and torques after contacting with that. For object manipulation, we can define several goals, e.g. turning a switch, opening a door, polishing a surface, translation of a vehicle engine in a production line, etc. One of the most important things which are studying in object manipulation is how body and robotic arms are relating. This process is called grasp.

A good grasp must have several properties which categorized in five principal groups, i.e. force closure, equilibrium, stability, dexterity and dynamic response (Hester et al., 1998). Thus an index must be used to satisfy these grasp properties. Several researches had been done on grasp planning in two last decades. Some non-dimensional indices are defined to evaluate grasp function. In one vision (Cheraghpour et al., 2009), grasp principal properties are classified into three main groups. In the first group, the indices choose the appropriate grasping points on object, which shows itself in equations by grasp matrix, represent the kinematics parameters of robot arm and grasped object. In the second group, the indices choose the appropriate configuration of robotic arm. Since there are several responses for accessing of a robot arm to a point in work space by calculation of inverse kinematics, the answer must satisfy kinematics specifications like dexterity and move capabilities. In the third group, the indices are related to kinetics of robot manipulator and grasped body after grasp process and during the manipulation.

In other vision (Byoung et al., 2001), other non-dimension indices are presented which included other grasp properties like stability grasp index, uncertainty grasp index, maximum force transmission ratio index, task isotropy index and stiffness mapping-based grasp isotropy index. With

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these in mind, Multi Aspect Grasp (MAG) performance index (Cheraghpour et al., 2009) is chosen to evaluate the grasp quality for object manipulation in the predefined task.

Numerical solution methods are powerful tools which can be used to solve problems, especially in nonlinear problems numerical methods are more suitable and useful than analytical solutions. Among all these methods, Particle Swarm Optimization (PSO) method and Genetic Algorithm (GA) are used so widely in solving problems (Mannepalli et al., 2010). These methods, especially PSO method, are developed so widely in recent years (Kaviani, Fathi, Farokhnia and Ardakani, 2009). Besides, PSO and GA method are so fast and easy to use and their results are so trustworthy (Martinez et al., 2009).

In this paper, Particle Swarm Optimization (PSO) method and Genetic Algorithm (GA) would be used to find the best grasping point of two different objects according to maximizing the MAG performance index and the results would be compared with each other.

2 THE MAG INDEX

The Multi Aspects Grasp (MAG) performance index is defined as (Cheraghpour et al., 2009):

$$MAG = \frac{1}{\Delta t}\int_{t_0}^{t_f}\left[W_1 C_N + W_2\frac{D_i}{D_{i\max}} + W_3\left(1-\frac{P_i}{P_{i\max}}\right)\right]dt \qquad (1)$$

where t_0 and t_f denote initial and final times of simulation respectively, $\Delta t = t_f - t_0$, weighting factors W_1, W_2 and W_3 are defined to put different emphasizes on each term. In Eq. 1 C_N is defined as the inverse of condition number of grasp matrix, i.e. G:

$$C_N = \frac{\sigma_{\min}(G)}{\sigma_{\max}(G)} \qquad (2)$$

Also, the term D is related to move ability of robotic arm and defined as:

$$D = \sqrt{\det\left(J^* J^{*T}\right)} \qquad (3)$$

where J^* denotes the Jacobian matrix which maps robotic arm joints velocity space to grasped object center of gravity velocity. Finally, the term P is related to power consumption of robotic actuators and defined as:

$$\int P dt = \int\left[\left|\dot{\theta}^T\right| . |\tau|\right]dt \qquad (4)$$

Note that in Eq. 1 the terms D_{max} and P_{max} denoted the maximum values of D and P respectively in the predefined task.

3 PSO METHOD

Particle Swarm Optimization (PSO) is a global optimization method which is presented first by Russell and Kennedy in 1995 (Atyabi et al., 2009). PSO is a search method which is inspired from the group behavior of animals like birds and fishes. The main advantageous of PSO over other optimization methods is the plenty existence of particles. Besides, in nonlinear problems derivations of performance index are so sophisticated whereas PSO is needless of performance index derivations which made this method so useful in solving nonlinear problems.

In this method, every particle is the representative of problem solution which is moving in the search space until approaches to the best position. At starter, the position and velocity of every particle are chosen randomly and then the value of particles is calculated based on a merit criterion by moving in the response space. Thus all particles accelerated toward the best solution of problem step by step. There is a memory is PSO which can save the best position gained by every particle in P_i and the best position gained by all particles in P_g during simulation and in every step, i.e. iteration. The velocity of particles is corrected by random coefficient in the direction of these two positions. This fact is shown by constraints Eq. 5 and Eq. 6 and Figure (1):

$$\vec{v}_i(t+1) = w\vec{v}_i(t) + c_1 R_1\left(\vec{P}_i(t) - \vec{x}_i(t)\right) + c_2 R_2\left(\vec{P}_g(t) - \vec{x}_i(t)\right) \qquad (5)$$

Where v_i and x_i are position and velocity of i-th particle respectively, R_1 and R_2 are random coefficients between 0 to 1 and c_1 and c_2 are arbitrary constants. Parameter t denoted the calculation step. Thus the new position of particles is calculated as:

$$\vec{x}_i(t+1) = \vec{x}_i(t) + \vec{v}_i(t+1) \qquad (6)$$

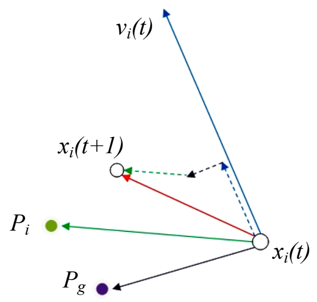

Figure 1: Principle of PSO method and the process of achieving to new position.

The term inertia weight w in Eq. 5 is declined linearly with time:

$$w = (w_1 - w_2) \times \frac{(\max iter - t)}{\max iter} + w_2 \qquad (7)$$

where w is inertia weight, w_1 and w_2 are the initial and final inertia weights respectively, t is the iteration step and *maxiter* is the termination iteration. The inertia weight term control the effectiveness of one step back velocity on the solution finding task.

4 SIMULATION

4.1 Robotic Manipulator

Figure (2) shows a robotic manipulator performing the object manipulation task, i.e. moving the object through the predefined path. The system includes a RRR manipulator. The inertial and geometrical parameters of manipulator arms are shown in Table (1). Note that the unit of I_{xx}, I_{yy} and I_{zz} in Table (1) is kg.m^2.

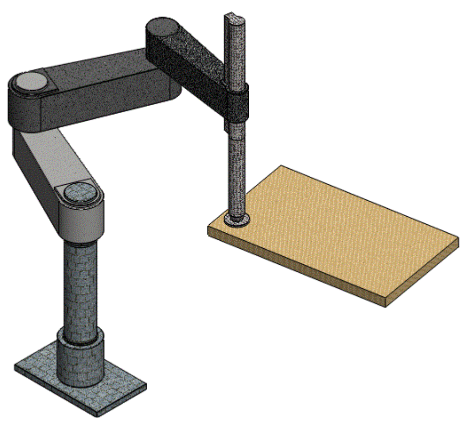

Figure 2: The SCARA type manipulator grasps a rectangular object.

Table 1: Manipulator inertial and geometrical parameters.

Link	L[m]	m[kg]	I_{xx}	I_{yy}	I_{zz}
1	1.04	17.4	0.130	0.524	0.539
2	1.04	17.4	0.130	0.524	0.539
3	0.92	6.1	0.015	0.212	0.192

4.2 Task

The task is moving the object on the straight line along X-axis. Joints trajectory are quintic functions as follows (Craig, 2005):

$$\begin{aligned} &X(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5 \\ &Y(t) = 1 \\ &\psi(t) = 10^0 \\ &t_f = 5\,(\mathrm{sec}) \end{aligned} \qquad (8)$$

The predefined path, grasping point coordinates with respect to object center of mass and also the DH coordinates of each link of the manipulator are shown in Figure (3).

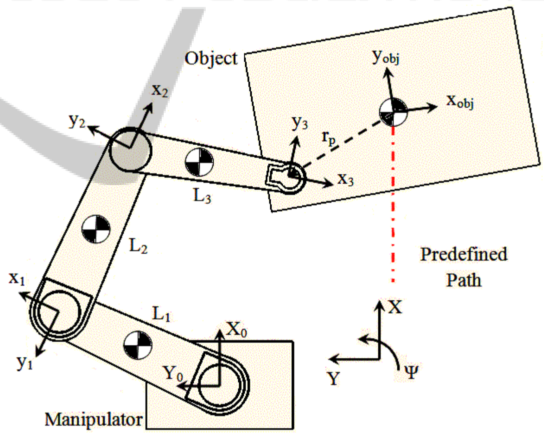

Figure 3: Predefined path for object center of mass in a 2D task, the position of grasping points with respect to C.G. of object and DH coordinates.

The grasp is supposed to be solid, i.e. the object orientation cannot change with respect to the End-Effector. The MAG index is calculated for two types of objects, i.e. $1.25^m \times 0.55^m$ rectangular (No.1) and $2^m \times 0.3^m$ long bar (No.2). The inertial parameters of objects No.1 and No.2 are shown in Table (2).

Table 2: Grasped objects inertial parameters.

Object No	m [kg]	I_{xx}	I_{yy}	I_{zz}
1	22.27	0.565	2.903	3.461
2	19.44	0.149	6.483	6.626

Note that the unit of I_{xx}, I_{yy} and I_{zz} in Table (2) is kg.m^2.
Also weighting factors W_1, W_2 and W_3 in Eq. 1 are supposed to be equal, i.e. all the terms have the same importance in object manipulation task.

4.3 PSO Method Parameters

We developed a program for calculation of MAG index from object surface points which is coded in MATLAB program. Basic PSO parameters which are illustrated in Eq. 5, Eq. 6 and Eq.7 are shown in Table (3) (Shi and Eberhart, 1999).

Table 3: Basic PSO parameters.

Parameters	Objects No.1 and No.2
V_{max}	1
V_{min}	0
x	-
y	-
c_1	1.4
c_2	1.4
w_1	0.4
w_2	0.9
Agents	20 particles
Elimination time	60 iterations

where V_{max} and V_{min} are the upper and lower boundary values of initial velocity respectively, x and y are initial values of grasping points position with respect to object center of mass which are randomly selected on the object surface, c_1 and c_2 are fixed constants in Eq. 5, w_1 and w_2 are the initial and final inertia weights respectively used in Eq. 7 (Samanta and Nataraj, 2009), agents and elimination time are the number of particles which search in response space and the total iterations needed to converge the answers respectively which are obtained heuristically (Atyabi et al., 2009). Note that agents are the representatives of the problem solution, i.e. the best grasping points of object which maximize the MAG index.

4.4 GA Parameters

We use MATLAB Genetic Algorithm toolbox to maximize MAG index and find the position of the best grasping point. In the toolbox, MAG index and the geometrical dimensions of object are selected as fitness function and inputs respectively. The simulation parameters are shown in Table (4). Generation and population size are obtained heuristically, i.e. more generation and population size values do not make any differences is results and these are the minimum values that results needed to be converged. Since there is no constraint in problem, mutation function is selected as constraint dependant. Other parameters are selected according to their definition (Goldberg, 1997).

Table 4: GA parameters.

Parameters	Object No.1 and No.2
Population size	20
Fitness scaling function	Rank
Selection function	Stochastic uniform
Crossover fraction	0.8
Crossover function	Scattered
Mutation function	Constraint dependant
Generation	40
Migration fraction	0.2
Migration interval	20

5 RESULTS AND DISCUSSION

The results of MAG index value obtained from PSO method for rectangular (No.1) and long bar (No.2) objects are shown in Figure (4) and Figure (5). The results show that the MAG value for both rectangular and long bar object is about 89 percent for the best grasping point.

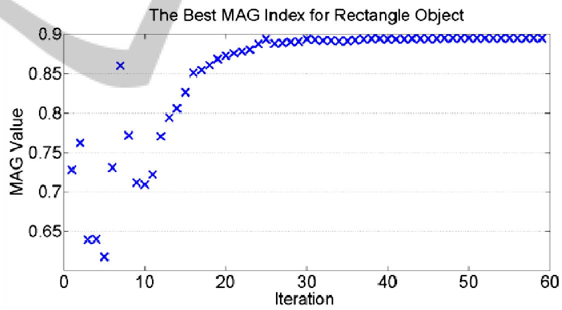

Figure 4: MAG index value for the best grasping point for rectangular object calculated by PSO method.

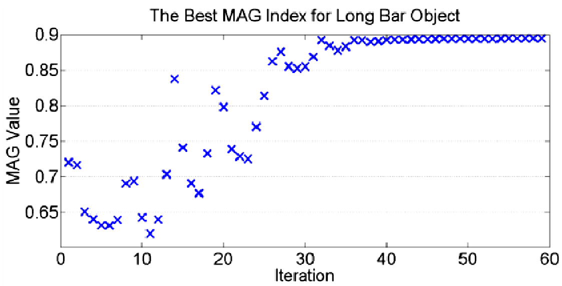

Figure 5: MAG index value for the best grasping point for long bar object calculated by PSO method.

The best grasping points of objects obtained from PSO method are shown in Figure (6) and Figure (7). The results show that the best grasping points are closed to object center of gravity. It is analytically proved that the best grasping point must be closed to the object center of gravity, i.e. the maximum MAG performance index value is belong to the best grasping point which is the object center of gravity (Cheraghpour et al., 2010).

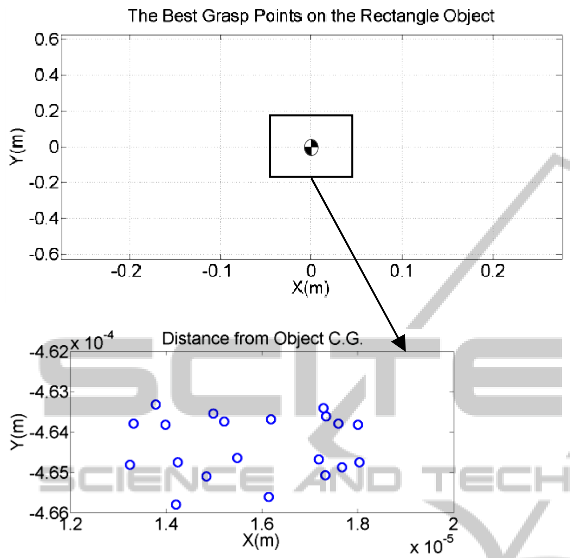

Figure 6: The best grasping points for rectangular object calculated by PSO method and their magnified positions.

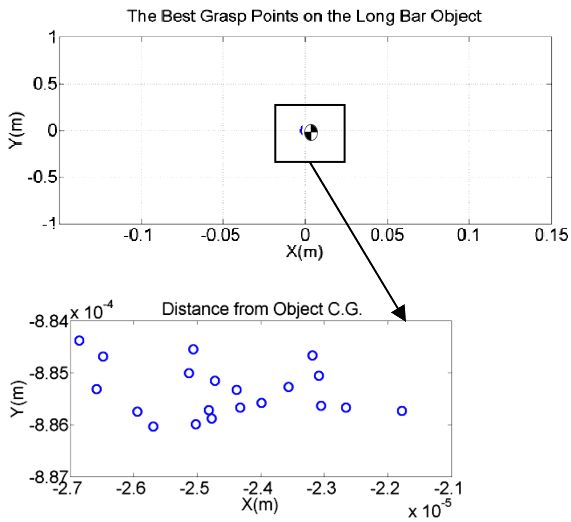

Figure 7: The best grasping points for long bar object calculated by PSO method and their magnified positions.

The results obtained from GA for object No.1 and object No.2 are shown in Figure (8) and Figure (9). The results show that MAG index value for rectangular and long bar object are about 84 and 83 percent respectively for the best grasping point which is closed to object center of gravity (Cheraghpour et al., 2010).

Note that in Figure (8) and Figure (9), *1* and *2* represented the *x* and *y* coordinates of grasping point position respectively which are measured from object center of gravity.

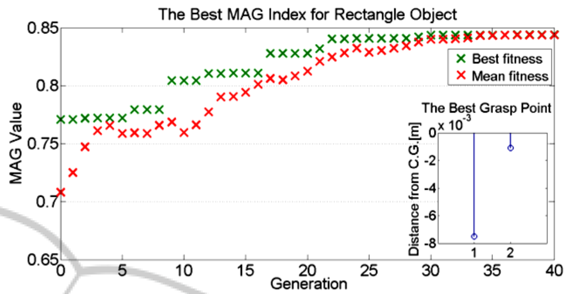

Figure 8: MAG index value for the best grasping point for rectangular object calculated by GA method.

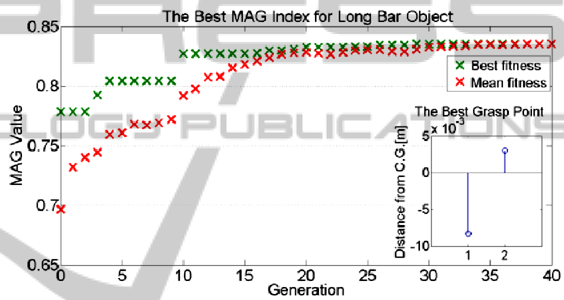

Figure 9: MAG index value for the best grasping point for long bar object calculated by GA method.

The results show that maximum MAG index value which is obtained from PSO method is more than GA method, i.e. MAG index value obtained from PSO method for both object NO.1 and object NO.2 is 89 percent whereas MAG index value obtained from GA for object NO.1 and object are 84 and 83 percent respectively for the grasping point which is closed to object center of gravity. Besides, the best grasping point obtained from PSO method is closer to object center of gravity than the result of GA one.

Also, program processing times on an Intel CPU 2.8 GHz for GA and PSO method are shown in Table (5).

Table 5: A comparison between approximated processing time of GA and PSO methods.

	time (sec)	time (sec)
Method	object No.1	object No.2
PSO	236	238
GA	150	152

The Table (2) shows that GA is converging faster than PSO method, i.e. processing time of GA is less than PSO method.

6 CONCLUSIONS AND FUTURE WORK

In this paper, MAG performance index is selected to evaluate grasp quality of object manipulated in the predefined path. Two numerical solution methods were used and compared with each other. Particle Swarm Optimization (PSO) method and Genetic Algorithm (GA) were used to maximize this index and find the best grasping point for object manipulation in the predefined task. Two different kinds of objects were used as the case studies. The results show that the maximum value of MAG index obtained from PSO method is more than maximum value which is obtained from GA one. Besides, both methods show that the best grasping point is closed to object center of gravity, which was analytically proved. Also the results of GA method are converged faster than PSO method but with different accuracies, i.e. PSO method had more accurate results than GA one. Therefore, in faster object manipulation tasks, the GA method is more suitable than PSO method. Since, in accurate object manipulation tasks, the PSO method is preferred to GA method.

In the future, we would like to do this procedure for unsymmetrical objects. Also for spatial and wheeled mobile manipulators (WMM), which has the geometrical constraints of object and the manipulator is more sophisticated, the problem could be more interesting. For online problems, e.g. facing to a new object, soft computing methods like neural networks, fuzzy logic and neuro-fuzzy would be used and compare.

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