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Optimization of Gripper by Using Ant Colony Metaphor

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Abstract

In the age of technology now, there are many innovations that can search work equally with the human, it is a robot. The technology handling robots are the most popular in the manufacturing industry and also in the medical system too. There are systems that the originators were sat up such as the sensor to measure the distance or using a lot of stain gauge or use the system photographs for check the change of semicircle material or using pneumatic in the gripper. Thus, this paper concern with to design the gripper that has the ability in the action of material handling by finding the optimum geometrical dimensions of a robot gripper. The problem is optimized by using an Ant colony metaphor with five objective functions, seven constraints and seven variables.

Keywords: Robotic gripper, optimization parameters, Ant colony metaphor.

Introduction

Grippers play an important role in automation systems. They are the interface between the work piece and the whole automation system which realizes a certain production process. Mostly a gripper design is a special and unique solution for handling task of a given work piece. Therefore the component ‘‘gripper’’ has a high impact on economical aspects, when flexible automation systems are needed. The two-finger grasp is extensively used both for human and industrial grip, since it may be considered the simplest efficient grasping configuration. Most of the gripping systems that are installed in industrial automations and robots are mechanical two finger grippers. They are used both for manipulation and assembling purposes since most of these tasks can be performed with a two finger grasp configuration. A gripper can be considered as a critical component of automated manipulations since it interacts with the environment and particularly with the piece to be machined or manipulated so that the gripper greatly contributes to a practical success of using an automated or robotized solution. Therefore, a good design of a gripper may be of fundamental importance. The design of a gripper must take into account several aspects of the components and the system together with the peculiarities of given application or multi-task purpose. Strong constraints for the gripping system can be lightness, small dimensions, rigidity, multi-task capability, simplicity and lack of maintenance. These design characteristics can be achieved by considering specific end effectors or grippers.

Literature

In the last two decades several researchers have studied the problem of grasping of a moving rigid object based on vision data. However the problem of grasping a moving and deforming object still remains unsolved. In this paper, they have presented the development of a fast algorithm for the computation of the optimal force on a slowly moving and deforming object so that grasp point could be known. Their main focus was to find the best grasp points as the object deforms, to track objects position at a future instant and then transfer gripper grasp to that location. At first the potential grasping configurations satisfying force closure are evaluated through an objective function that maximizes the grasping span while minimizing the distance between the object centroid and the intersection of the fingertip normal.

A population based stochastic search strategy was adopted by K.S. Venkatesh, A. Dutta, P. Guha and T. Mishra[1]. They conducted Experiments to prove that the object can be tracked in real time and the optimal grasp points can be determined so that a robot can capture it. This method works in real time so it has great potential for application in industries for grasping objects whose shapes are not clearly defined (e.g. cloth), deforming objects, or objects that are partially occluded.

G. Bretthauer D. Osswald, J. Martin, C. Burghart, R. Mikut and H. Wörn[2] This article presents the approaches taken to integrate a novel anthropomorphic robot hand into a humanoid robot. The requisites enabling such a robot hand to use everyday objects in an environment built for humans are presented. Starting from a design that resembles the human hand regarding size and moving ability of the mechatronical system, a low-level control system providing reliable and stable controllers for single joint angles and torques, entire fingers and several coordinated fingers. Also the high-level control systems connecting the low-level control system with the rest of the humanoid robot are presented finally some preliminary results of the system, which were currently tested in simulations, were presented

L. Saggere and S. Krishnan[3] This paper presents the design and development of a new tool, called the micro-clasp gripper, for accomplishing firm and stable gripping and manipulation of complex-shaped micro- scale objects in any orientation using a single rectilinear actuator. The micro-clasp gripper is a compliant mechanism comprised of end-effectors with a closed-loop boundary that can be folded and unfolded in a plane by the action of the rectilinear actuator. Upon actuation, the end-effectors of the micro-clasp gripper clasps an object by first encircling the object, and then, folding to the object to accomplish multi-point contact with the object. The design of the micro-clasp gripper is obtained through a systematic modeling and topology optimization techniques, and a proof-of-principle device is micro-fabricated using conventional micromachining techniques.

A multicriteria optimization of robot gripper design problem was solved using two different configurations involving two conflicting objectives and a number of constraints. The main objective was minimization of the difference between maximum and minimum gripping forces and simultaneous minimization of the transmission ratio between the applied gripper actuator force and the force experienced at the gripping ends (D. Rituparna and D. Kalyanmoy[4]).

Chiara Lanni and Marco Ceccarelli[5] have studied the mechanisms in two-finger gripper to formulate an optimum design configuration. The design problem formulated as a new optimization problem by using fundamental characteristics of grasping mechanisms. In order to optimize a mechanism for two-finger gripper, an basic multi-objective optimum algorithm was used by considering 4 different objective functions including index for grasping, encumbrance, acceleration and velocity for finger gripper with defined working area. The new formulation will achieve a kinematic design of gripper with optimal characteristics even as improvement of existing solutions.

A.M. Zaki, O.A. Mahgoub, A.M. El-Shafei, A.M. Soliman[6] was designed a gripper mechanism and implemented to grasp unknown objects with different masses, geometrical dimensions, and surface roughness. The design and control of the gripper system has considered for simplicity in the mechanical system and large variety of grasped objects and low cost. The proposed grasping mechanism process during object lifting and handling was mainly depending upon the slip reflex principle leads to object slipping, and dropping may also occur while gripping. On the other hand, applying extra force during grasping may lead to object damage. Hence a new system controller using fuzzy logic based on empirical investigation of the human hand skills has been proposed. Experimental confirmation was studied for of the distance of the slippage and process time and then simulation and experimental results were discussed.

S. Costo, G. Altamura, L.E. Bruzzone, R.M. Molfino and M. Zoppi[7] discussed with the design of the mechtronic device enabling the multi point grasping and firm hold of limp one layer of leather sheets for the automation of leather manufacturing industries. The design assures low inertia, high modularity and full flexibility to the environment.

Problem Formulation: For any optimization problem, the problem formulation is the first and foremost step. In the case of optimization of force of gripper, then problem is formulated as follows.

Consider the example of robot gripper the scheme of which is presented in figue-1.

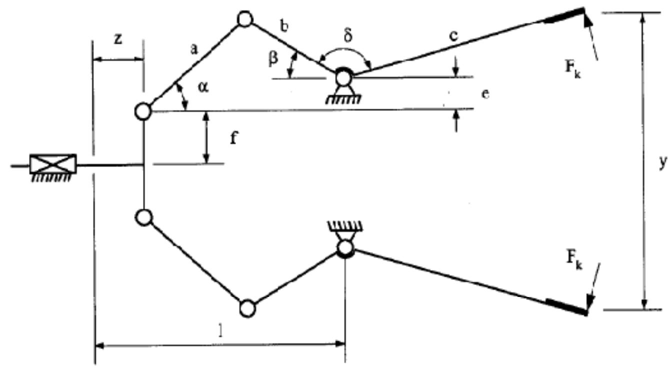

Figure-1
The scheme of robot gripper mechanism

Where, a,b,c and f are lengths of the links of the robot gripper, e=distance between the point C and the axis of the gripper, l=the distance between the point C and the gripper actuator, δ= is the angle between b and c links of the gripper and F_k=the gripping force exerted by fingers of robot gripper on the work piece to be handled.

The geometrical dimensions of the gripper mechanism are shown in figure-2

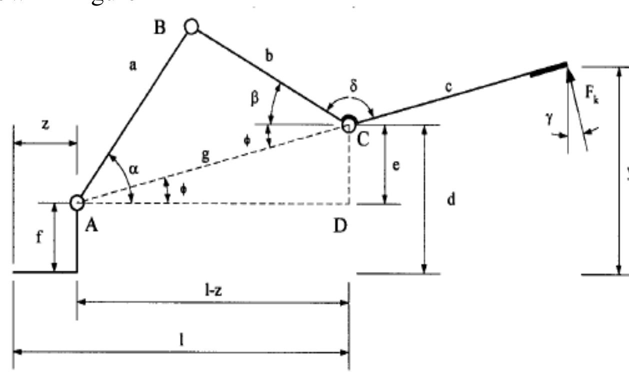

Figure-2
The geometrical dimensions of the gripper mechanism

From Δ ADC
$g^2 = (l - z)^2 + e^2$
$g = \sqrt{(l - z)^2 + e^2}$ (1)

$From$ Δ ACB
$b^2 = a^2 + g^2 - 2.a.g.\cos(\infty - \emptyset)$
$\infty = \cos^{-1}\left(\frac{a^2+g^2-b^2}{2.a.g}\right) + \emptyset$ (2)
$a^2 = b^2 + g^2 - 2.b.g.\cos(\beta + \emptyset)$
$\beta = \cos^{-1}\left(\frac{b^2+g^2-a^2}{2.b.g}\right) - \emptyset$ (3)

Where $\emptyset = \tan^{-1}\left(\frac{e}{(l-z)}\right)$
The distribution of the forces are presented in the figure 3 and from this figure we have taking moment about point C and $\sum M = 0$

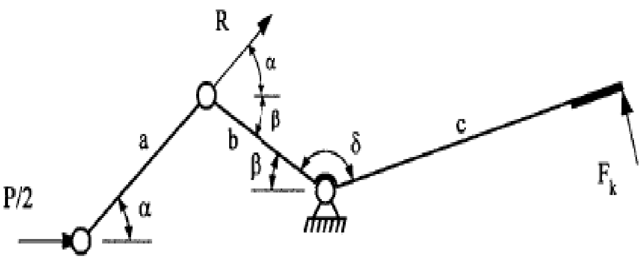

Figure-3
The force distribution in the mechanism of the gripper

$R.\sin(\infty + \beta) = F_k.c$
$R = \frac{P}{2.\cos\infty}$ (4)
$F_k = \frac{P.b.\sin(\infty+\beta)}{2.c.\cos\infty}$ (5)

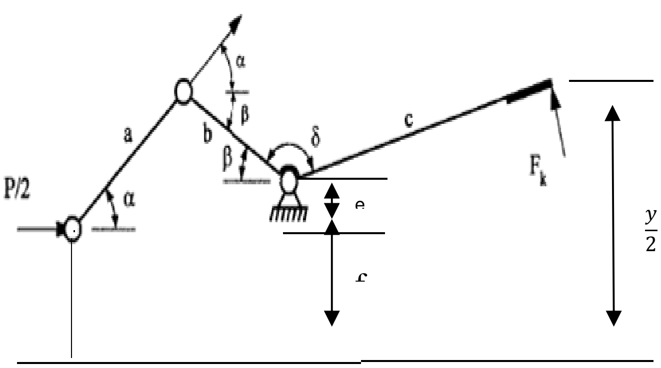

Figure-4
Dimensions of the gripper

From the figure 4maximum and minimal dimensions on the gripper can be calculated by the formula
$y = 2(e + f + c.\sin(\beta + \delta))$

Objective function: In this problem the following objective functions are considered

$f_1(X)$: The difference between maximum and minimum gripping forces for the given range of the gripper end displacements
$f_1(X) = |\max z\, F_k(X,z) - \min z\, F_k(X,z)|$ (6)

$f_2(X)$: The force transmission ratio between the gripper actuator and the gripper ends
$f_2(X) = \frac{P}{\min z\, F_k(X,z)}$ (7)

$f_3(X)$: The shift transmission ratio between the gripper actuator and the gripper ends.
$f_3(X) = \left|\frac{y(X,z_{max}) - y(X,z_{min})}{z_{max} - z_{min}}\right|$ (8)

$f_4(X)$: The lengths of all the elements of the gripper.
$f_4(X) = a + b + c + e + l$ (9)

$f_5(X)$:The efficiency of the gripper mechanism
$f_5(X) = \left|\frac{2.\max z\, F_k(X,z)}{P}\right|$ (10)

The problem contains five objective functions, it is necessary to find the combined objective function, by introducing weight age factors it can be done in three cases. In the first case the combined objective function has the first two objective functions. In the second case, the combined objective function has the last three objects functions. In the third case, the combined objective function has all the five objective functions
For the first case$\boldsymbol{F_1(X)} = \left\{\left[\frac{w_1 f_1(X)}{f_1^*}\right] + \left[\frac{w_2 f_2(X)}{f_2^*}\right]\right\}$
Where the objective functions $f_1(X), f_2(X)$ are minimization functions w_1, w_2 are the weightage factors for objective functions $f_1(X), f_2(X)$ respectively.

$f_1^* = 100, f_2^* = 1$ are the normalizing parameters to bring all objective functions in the same decimal point and unitless

Design variables: a,b,c and f are lengths of the links of the robot gripper, e=distance between the point C and the axis of the gripper, l=the distance between the point C and the gripper actuator, δ= is the angle between b and c links of the gripper.

Design constraints: From the gripper geometry the following constraints can be derived
$g_1(X) = y_{min} - y(X, z_{max}) \geq 0$
$g_2(X) = y(X, z_{max}) \geq 0$
$g_3(X) = y(X, 0) - y_{max} \geq 0$
$g_4(X) = y_G - y(X, 0) \geq 0$
$g_5(X) = (a + b)^2 - l^2 - e^2 \geq 0$
$g_6(X) = (l - z_{max})^2 + (a - e)^2 - b^2 \geq 0$
$g_7(X) = (l - z_{max}) \geq 0$

Where, $y(x,z) = 2[e + f + c.\sin(\beta + \delta)]$Displacement of the gripper end, y_{min} - Minimal dimension of the gripper, y_{max} - Maximal dimension of the gripper, y_G - Maximal range of the gripper ends displacement, z_{max} - Maximal displacement of the gripper actuator.

Variable bounds: The upper and lower bounds on two design variables are $10 \le a \le 150$, $10 \le b \le 150$, $100 \le c \le 200$, $0 \le e \le 50$, $10 \le f \le 150$, $100 \le l \le 300$, $1 \le \delta \le 3.14$

Ant colony algorithm: Behavior of ants was the inspiration for the ant colony optimization algorithm (ACO), is a probabilistic technique for solving computational problems which can be further reduced to finding good paths through graphs. This technique is a member of ant colony algorithms family belongs to swarm intelligence methods. The first algorithm was focused, to search for an optimal path in a graph; based on the ants behavior seeking a path between their colony and the food source.

Procedure ACO _Metaheuristic
While (not_termination)
Generate Solutions()
Daemon Actions()
Pheromone Update()
End while
end procedure

Edge Selection: An ant will move from node i to node j with probability $P^{k}_{1j} = \frac{(\tau_{ij}^{\alpha})(\eta_{ij}^{\beta})}{\Sigma(\tau_{ij}^{\alpha})(\eta_{ij}^{\beta})}$

Where, $\tau_{i\,j}$ is the amount of pheromone on edge i, j, α is a parameter to control the influence of $\tau_{i\,j}$, $\eta_{i,j}$ is the desirability of edge i,j (a priori knowledge, typically $1 / d_{i,j}$), β is a parameter to control the influence of $\eta_{i,j}$

Pheromone Update: $\tau_{i\,j} = (1 - \rho)\, \tau_{i\,j} + \Delta\, \tau_{i\,j}$

Where, $\tau_{i\,j}$ is the amount of pheromone on a given edge i,j, ρ is the rate of pheromone evaporation and $\Delta\ \tau_{i\,j}$ is the amount of pheromone deposited, typically given by

$$\Delta\tau_{ij} = \begin{cases} Q/L_k & \text{if ant } k \text{ uses } ij \text{ in its tour} \\ o & \text{otherwise} \end{cases}$$

Where L_k is the cost of the k^{th} ant's tour (typically length). And Q is the constant

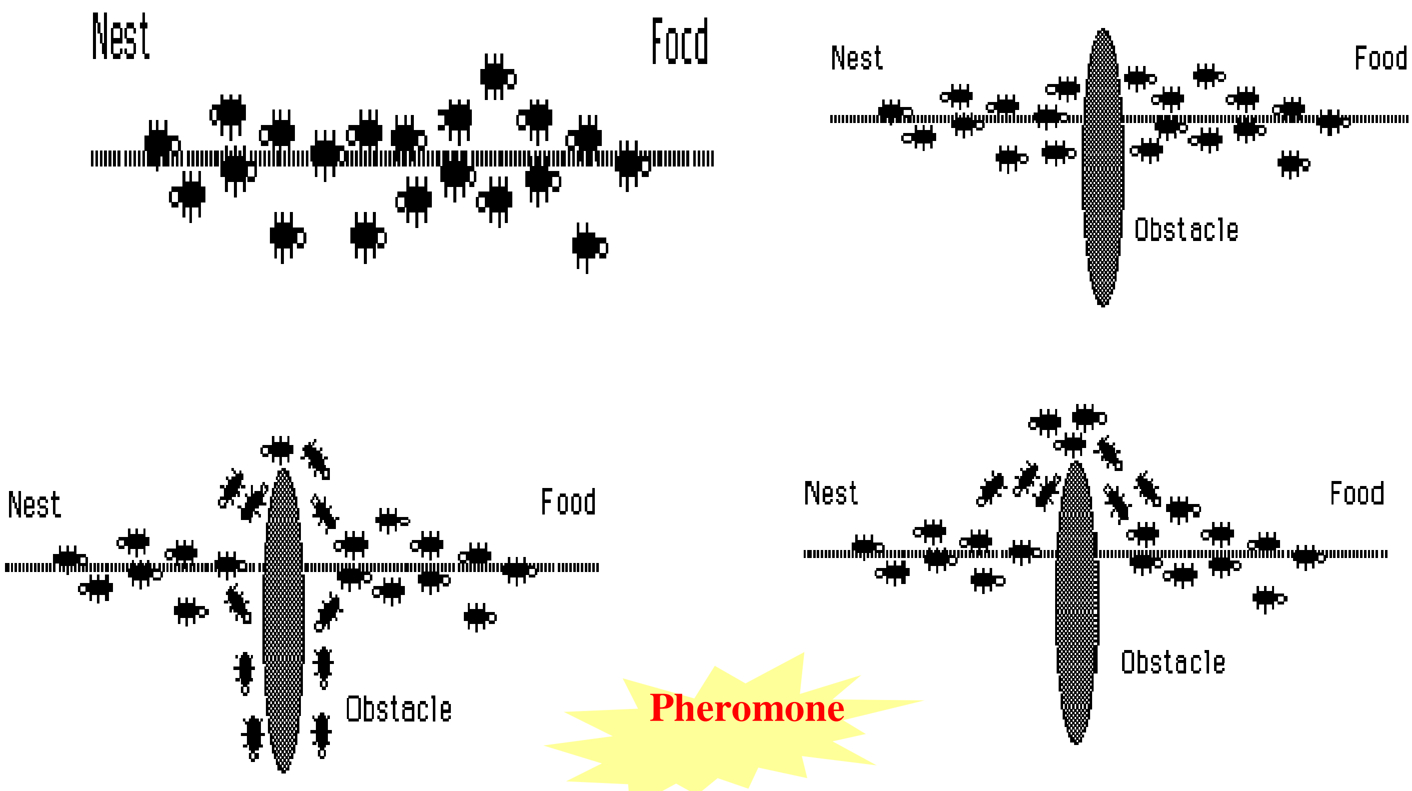

Figure-5
Behavior of Ants

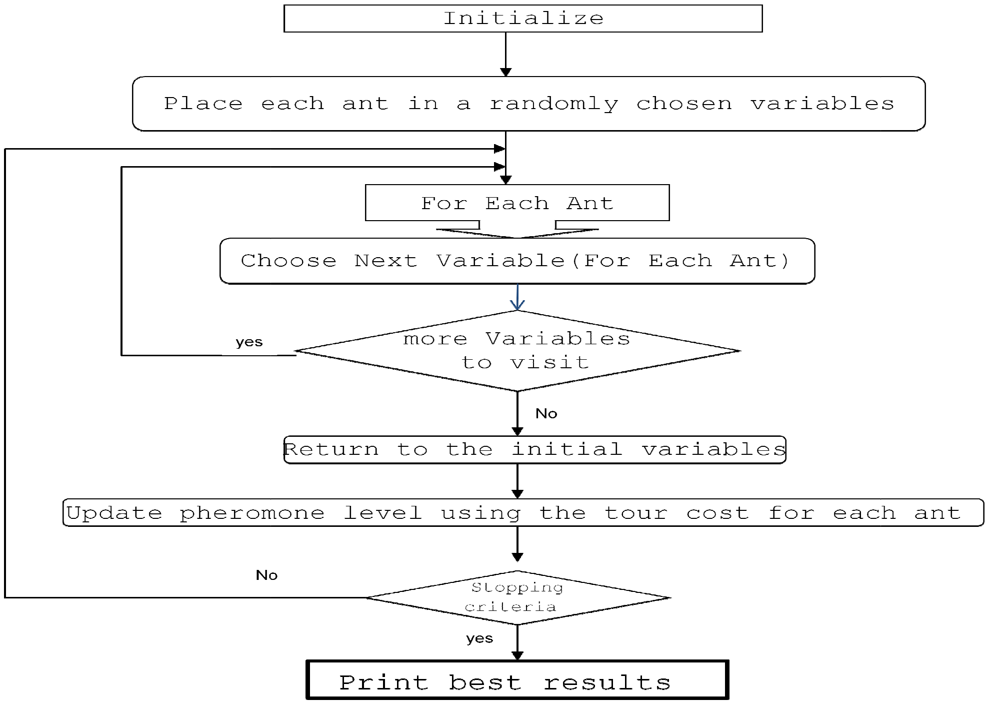

Figure-6
Flowchart for Ant colony Algorithm

Table-1
Optimum solution obtained by using ACO

w1	w2	a	b	c	e	f	l	delta	F
1	0	136	133.2	200	8	26	156	2.5836	0.027824
0.9	0.1	136	133.2	100	8	26	156	2.07	0.144139
0.8	0.2	136	133.2	100	8	26	156	2.0272	0.232629
0.7	0.3	136	133.2	100	8	26	156	2.5836	0.321119
0.6	0.4	136	133.2	100	8	26	156	2.5836	0.409609
0.5	0.5	136	133.2	100	8	26	156	2.5836	0.4981
0.4	0.6	136	133.2	100	8	26	156	2.5836	0.58659
0.3	0.7	136	133.2	100	8	26	156	2.5836	0.67508
0.2	0.8	136	133.2	100	8	26	156	2.5836	0.76357
0.1	0.9	136	133.2	100	8	26	156	2.5836	0.85206
0	1	147.2	150	100	0	10	132	1.6848	0.715384

Problem description: A typical input data required to develop a mathematical model for robot gripper design is
Minimal dimension of the gripper, y_{min}=50 mm
Maximal dimension of the gripper, y_{max}=100 mm
Maximal range of the gripper ends displacement, y_G=150 mm
Maximal displacement of the gripper actuator. z_{max}=100 mm
Actuating force, P = 100 N

Input parameters
Pheromone Update for ACO (ρ) =0.1
Number of iterations =50
Number of ants =50

Fixing up the above parameters is a very crucial in an optimization problem because there are no guide lines for these. One has to fix the ACO parameters for a particular depending on the convergence of the problem as well as on solution time. After executing various run with different ACO parameters depending on convergence of the value.

One of the important factors that influence the performance of ACO is the Number of Ants. The number of iterations taken for convergence comes down as the number of Ants increases. Because of the random nature of the search, it is extremely difficult to arrive at an optimal number of Ants.

Results and Discussions

The values of best design variables and the constraints for the 100 iteration obtained after running the program for Ant colony algorithm, written in the C-language is given below

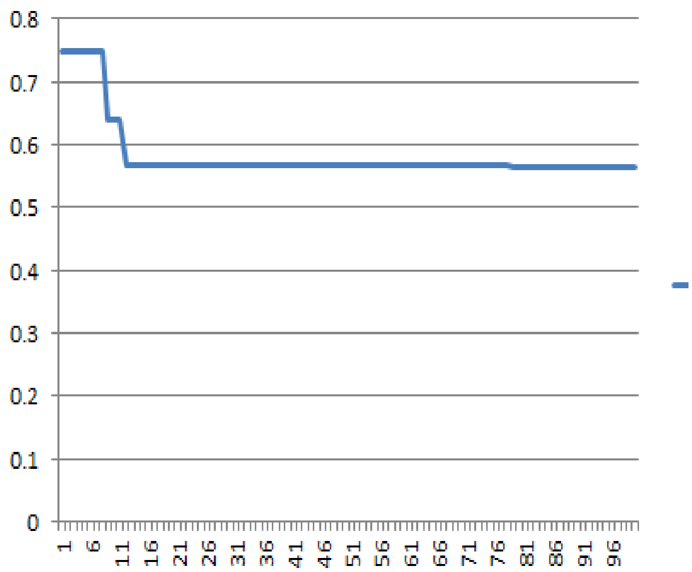

Figure-6
Graphical representation of ACO Function

The graph shows the way in which optimum values are obtained, fig 6 show the values of final objective function (i.e. combination of function1 and function2) from ACO

Conclusion

In this project a new multicriterian optimization method based on swam intelligence techniques are presented. The main aim of these methods are to reduce the computing time while running an evolutionary algorithm program and to facilitate the decision making process with multi objectives. This means that the methods make the process of seeking the best solution more effective considering both the computation time and the decision-making problem.

References

1. Venkatesh K.S., Dutta A., Guha P. and Mishra T., Stochastic re-grasp planning for vision aided capture of deforming and moving object, **19(4),** 510–519 **(2009)**
2. Bretthauer G., Osswald D., Martin J., Burghart C., Mikut R. and Wörn H., Integrating a flexible anthropomorphic, robot hand into the control, system of a humanoid robot, **48(4)** 213–221 **(2004)**
3. Saggere L. and Krishnan S., Design and development of a novel micro-clasp gripper for micromanipulation of complex-shaped objects, **38(12),** 1509-1522 **(2003)**
4. Rituparna D. and Kalyanmoy D., Optimizing and Deciphering Design Principles of Robot Gripper Configurations Using an Evolutionary Multi-Objective Optimization Method, February 10, 2011 KanGAL Report Number 2011002 **(2011)**
5. Cutkoski M.R., On Grasp Choice, Grasp Models and the Design of Hands for Manufacturing Tasks, *IEEE Trans. Robot. Automat*, **5(3),** 269– 279 **(1989)**
6. Zaki A.M., Mahgoub, El-Shafei A.M. and Soliman A.M., Design and Implementation of Efficient Intelligent Robotic Gripper, **9(11), (2010)**
7. Costo S., Altamura G., Bruzzone L.E., Molfino R.M. and Zoppi M., Design of a re-configurable gripper for the fast robotic picking and handling of limp sheets, Proc. Of the 33rd International symposium on robotics, Stockholm, Sweden, 7-11 **(2002)**
8. A. Osyczka. Evolutionary algorithms for single and multicriteria design optimization, Heidelberg: Physica-Verlag, **(2002)**
9. Brown R.G. and Brost R.C., A 3-d Modular Gripper Design Tool, IEEE International Conference on Robotics and Automation Proceedings, 2332-2339 **(1997)**
10. Lanni C. and Ceccarelli M., An Optimization Problem Algorithm for Kinematic Design of Mechanisms for Two-Finger Grippers, The Open Mechanical Engineering Journal, 3 **(2009)**