IJCSN - International Journal of Computer Science and Network, Volume 7, Issue 3, June 2018
ISSN (Online): 2277-5420
www.IJCSN.org
Impact Factor: 1.5

Towards Hybridization of Nature Inspired Metaheuristic Techniques for Collision Free Motion Planning

Dr. Sapna Katiyar

Professor, ABES Institute of Technology, Ghaziabad

Abstract - Various heuristic and metaheuristic algorithms were proposed in early 70s. Metaheuristic algorithms are very simple, flexible, derivation free mechanism and are superior to others conventional optimization techniques. They make use of domain specific knowledge and is controlled by upper level strategy, they are approximate and usually non deterministic. This paper proposes a newly developed hybrid metaheuristic algorithm (MACOCS) inspired by the behavior of ants and cuckoo birds. Path planning is very sensitive issue of mobile robot movement, here developed MACOCS technique is applied on it to find out collision free optimized path in environment having static and dynamic obstacles both. The results show that MACOCS provides competent results as compared to modified ACO and Cuckoo Search algorithms. It also shows that the proposed algorithm can also be successfully applied to any challenging problems with unknown search space.

Keywords - Cuckoo Search (CS), Hybrid MACOCS, Modified ACO, Metaheuristic, Optimization, Path Planning

1. Introduction

Optimization is a process of determining best or most favorable solution of any problem, therefore these techniques are actually the search methods and its main purpose is to find out the solution of complex problems by optimizing given quantity within certain set of constraints. Nature is a very rich source of inspiration, so almost all newly developed algorithms are known as nature inspired. In literature almost 40 different types of optimization algorithms have been described and used in number of applications, among them not all them are efficient while few are very popular. They are probabilistic search methods, which simulates the behavior of natural entities.

Now a days they have gained popularity among researchers because of their high efficiency but it is very challenging to identify the best suited algorithm among these for any application. In addition to this, day by day new algorithms have been developed to observe, whether they can adjust in this challenging environment or not [1].

Various types of optimization tools are: simulated annealing, evolutionary computation, tabu search, ant colony optimization, honey bee optimization, firefly algorithm, bat algorithm, grey wolf optimization, particle swarm optimization, cuckoo search, flood fill algorithm, artificial immune systems etc. Real world optimization problems are very challenging to solve and path planning is one of them. Several other applications are also there, which have to deal with NP hard problems and many problems have to be solved by trial and error methods. Some of the paths planning fields are: logistics, transportation, network management, game programming, operation management, system analysis, system design, project management etc.

The objective of the paper is:

- The development of hybrid algorithm which combines the advantages of ant colony optimization algorithm and cuckoo search algorithm
- Comparison of performance of hybrid algorithm with traditional algorithm for shortest distance, convergence time and error.

2. Motion Planning

Path planning or motion planning or navigation problem of mobile robot is actually very essential and significant in the field of robotics. Its aim is to provide the capability and power to mobile robot to plan their movements from one point to another so that they can perform various tasks in complex scenarios also. N. J. Nilsson has presented revolutionary work in the area of motion planning in year 1960. Till date researchers have developed and presented various motions planning techniques like: road maps (visibility graph, voronoi graph), cell decomposition, potential fields, rapidly exploring random trees, sampling based algorithm etc., each of them are having their own strength and weakness [2, 3]. Actually problem occurs mainly when obstacles come in between the path when mobile robot is moving, so it creates hindrance and degrade the overall performance of system. Surrounding environment may be static as well as dynamic and even the obstacle may be known or unknown, accordingly four combinations are there, which need to take care while planning the movement of mobile robot [4]:

Path planning in static environment: it consists of only static obstacles and may be of:

- With known static environment
- With unknown static environment

Path planning in dynamic environment: it consists of static as well as dynamic obstacles and may be of again two types:

- With known dynamic environment
- With unknown dynamic environment

The objective of robotics motion planning is to evaluate parameters in designates space by identifying the positions of robot, source, destination and static obstacles. Then there is a requirement to identify suitable path planning algorithm and search method, which identify the suitable path from source to destination and then optimize it as per requirement.

In traditional motion planning techniques, number of problem encountered like large computational time and cost. Therefore metaheuristic techniques for solving motion planning problems have drawn the attention of researchers. They are very effective and offer number of advantages like: very simple to understand and implement, fast convergence, capable to solve complex problem, can be easily implemented in real life applications and require very less parameters.

3. Ant Colony Optimization Algorithm

Ant colony optimization algorithm is inspired the behavior of real ant colonies. Ants are very social insects and they have captured the attention of researchers due to structured level of ant colonies. Ant Colony Optimization (ACO) algorithm is a category of swarm intelligence, and it is proposed by Marco Dorigo in year 1992 in his PHD thesis. ACO is a population based metaheuristic technique, which can be successfully applied to determine approximate solutions to a number of complex optimization real time problems [5, 6]. It is iterative and very adaptive in nature; its aim is to find out optimal path based on the searching behavior of ants between their colonies to food source. Some of population variations of ACO algorithms are proposed in literature, which are: Elitist ant system, Max-Min ant system, Ant Colony system, rank based ant system, continuous orthogonal ant colony, recursive ant colony optimization etc. In modified ACO, ants move from one node to other node with minimum distance and travel all the forward nodes reaching source. The distance from the source to destination is calculated covering all the nodes travelled by ant. During identification of shortest path ants do not move backward.

Actually ants move randomly in all direction and they have a tendency to release pheromone on the paths they are moving. Other ants follow the path having high intensity of pheromone and by this way they give probabilistic solution regarding a possible path from source to nest, and it is known as tour. Probability rule depends on two components mainly [7, 8]: heuristic and metaheuristic. Pseudo Random Proportional Action Rule is a probability rule, which can be successfully applied between any two nodes.

3.1 Edge Selection: Trail level shows the posteriori indication of movement desirability. Usually trails are updated, when all ants complete their solutions, increasing the level of trail gives good solution while decreasing trail level gives bad solution. Generally any ant, moves from one node to another by the probability rule:

$$p_{ij} = \frac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{l \in k}[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}} \quad \text{------ (1)}$$

Here,

τ_{ij}: the amount of pheromone on the edge (from i to j)
η_{ij}: desirability of state transition, it is the inverse of the distance between the two cities ($1/d_{ij}$) and d is the distance
α :the parameter which control the influence of τ_{ij} and ($0 \leq \alpha$)
β: the parameter which control the influence of η_{ij} and ($\beta \geq 1$)

3.2 Pheromone Update:

The objective of pheromone update is to increase the value of pheromone, which is associated with good solutions while decreasing others related to bad solutions. Two ways to achieve this is: either by decreasing the pheromone values by pheromone evaporation or by increasing pheromone values by selecting good solutions.

Start
Initialize Parameters
Initialize Pheromone Trails
Generate ant
While
criteria not satisfied
do
all ants should construct their solutions
update pheromone
end while
obtain best solution
Stop

Pseudo code of MACO

There are two possible ways via which every ant modifies the environment:

- **Local trail updating**: whenever ant move from one node to another node, then value of pheromone is updated by equation no. (2):

$$\tau_{ij}(t) = (1-\rho)\tau_{ij}(t-1) + \rho\tau_0 \quad \text{----- (2)}$$

Here,
ρ: evaporation constant
τ_0: initial value of pheromone trails
value of pheromone trail can be calculated by the equation no (3):

$$\tau_0 = (n.L_{nn})^{-1} \quad \text{--------- (3)}$$

Here,
n: total number of cities
L: total created tour length by using any one of the construction heuristics

- **Global trail updating**: When all the ants have completed a tour then they are able to determine the shortest route, by updating the edges available in its path using the equation no (4):

$$\tau_{ij}(t) = (1-\rho).\tau_{ij}(t-1) + \frac{\rho}{L^+} \quad \text{-------- (4)}$$

Here,
L^+:best path length created from source to nest

4.0 CUCKOO SEARCH OPTIMIZATION ALGORITHM

Cuckoo Search (CS) is also a population based optimization technique like other metaheuristic techniques, defined by Xin She Yang and Suash Deb in year 2009. Cuckoo birds have beautiful sound and are very fascinating because of their aggressive reproduction strategy [9,10]. It is inspired by obligate brood parasitism because these species have a tendency to laying their eggs into the nest of other host birds of other species. Such breeding behavior of cuckoo can be successfully applied to solve various optimization problems related to real life applications. Sometimes it can outperform than other algorithm.

To define CS, three idealized steps are there:

- Each cuckoo lays only one egg at a time and cuckoo dump its egg into chosen nest randomly
- For next level of generation, high quality of eggs with best nest will carry over
- If number of available host nest is fixed, host bird can discover unfamiliar egg with a probability $P_a \epsilon [0, 1]$. It means host bird can either throw the egg away or abandon the nest to build a new one at new location.

Based on above three steps, the basic steps of cuckoo search can be summarized in the form of pseudo code, defined as [11]:

Start
Objective Function, Y(X), $X=(X_1, X_2, X_3, \ldots X_z)^T$;
Create initial population of N host nests X_i (i=1, 2, 3, …n);
While (t < maximum generation) or (stop criteria);
a cuckoo randomly and evaluate its quality or fitness function (say F_i);
Randomly select a nest among N (let us say, j);
If (Fi >Fj)
Now replace the value of j by new solution;
end if
poor nest is discarded and new one is build;
keep the nest with quality solution;
rank the solution and obtain the current best solution;
pass the current best solution to next generation;
end while

Pseudo code of CS

5.0 HYBRID MACOCS ALGORITHM

The proposed algorithm is the hybridization of ant colony optimization with cuckoo search algorithm. It combines and uses the advantages of both algorithms. In ACO, ants move on the path having more intensity of pheromone but this sequential process makes the system slow, so its takes relatively more time to solve combinatorial optimization problems [12].

Therefore CS is used to overcome this drawback, i.e. slow performance of local search in ACO and hence by using Cs local search is performed at a much faster rate in comparison to ACO [13, 14]. CS performs better in local search as it has only one parameter to control besides population size [15, 16].

Below mentioned the steps are for proposed hybrid MACOCS algorithm:

1. Initialization of parameters
2. Insert number of nodes in grid matrix
3. Passing through from each node using hybrid MACOCS algorithm
4. Allocate each ant to different node and here //MACO algorithm starts//
5. Local search is done by cuckoo search algorithm
6. Then initialize nest and cuckoo search algorithm starts //CS algorithm starts//
7. Determine the current best nest
8. While (F_{min}> maximum generation)
9. Obtained the cuckoo by randomly walking if it is not replaced by search process
10. End while
11. Calculating the fitness quality by randomly selecting any nest among k (let us say m)
12. If (F_n>F_m), replace the value of m by new solution otherwise preserve the best solution and nest
13. Now select next city according to the fitness value of cuckoo search //CS algorithm ends//
14. Each ant update pheromone value and evaluate fitness function
15. If total number of iterations is less than maximum number of iterations then go to step no. 3, otherwise terminate the program // MACO algorithm ends//
16. Travel each node once and move forward towards another nodeby avoiding obstacles until does not reach at destination, otherwise repeat from step no. 3 to step no.16.
17. Stop

Table1- Parameters of hybrid MACOCS algorithm:

MACO parameters	CS parameters
No. of ants: 100	Maximum generation: 250
No. of iterations: 250	Population size: 150
Population size: 150	Step size, α: 1
Real parameters α and β: 1.0	Probability of eggs: 0.5
Heuristic value, η: 1	Discovery rate, P_d: 0.2
Evaporation rate, ρ: 0.7	

6.0 RESULTS AND DISCUSSIONS

In this proposed paper for every metaheuristic technique, some control parameters are chosen for their efficient working. An extensive survey and analysis have been done to identify and to select the values of these control parameters, most of the standard values have been taken here and they also suits well for this research.

Table 1 shows the standard parameter for the simulations. Simulation is done on windows platform with Matlab R2013a framework.

In our simulation we have compared MACO, CS & Hybrid MACOCS algorithms for shortest distance, convergence time & % error by varying the number of cities.In Fig. 1 & 2 graphs compare the results of convergence time for MACO, CS & Hybrid MACOCS. Table 2 shows the convergence time. Fig. 3 & Fig 4 compare the results of different algorithms for shortest distance travelled by the mobile robot from source to destination avoiding static and dynamic obstacles. Table 3 shows the shortest distance.

Also all the three techniques are compared in terms of % error occurred, same data is calculated and represented in Table 4 and respective comparison is shown in Fig. 5.

Various experiments have been done by varying the number of cities and then compared all achieved values for different techniques. Time is calculated in seconds. The results achieved here are compared in terms of convergence time, distance travelled and percentage error for MACO, CS and MACOCS to test the efficiency.

By comparing results of all three mentioned metaheuristic techniques, it has been observed that MACOCS is converging very fast with shortest distance by varying no. of cities. So it is evident with the results that hybrid MACOCS gives better results as compared to MACO and CS.

Table 2-Time taken to move from source to destination

Number of city	MACO	CS	Hybrid MACOCS
20	4.0526	6.5031	2.9821
35	5.9812	3.8987	2.7019
50	7.1953	7.6592	3.6739
68	6.9929	9.0107	3.9901
75	7.2012	10.7603	4.5305
89	8.8902	12.9179	4.7051
100	10.1021	15.0782	4.9918
120	12.0102	18.0981	6.2931

145	15.3127	19.2065	8.0163

Table 3-Distance covered from source to destination

Number of city	MACO	CS	Hybrid MACOCS
20	289.038	280.693	229.972
35	323.907	349.537	251.237
50	350.884	398.982	276.692
68	400.563	440.672	288.037
75	443.702	453.638	291.759
89	489.293	513.592	303.799
100	502.937	598.671	330.658
120	598.054	634.769	399.305
145	713.398	870.905	411.904

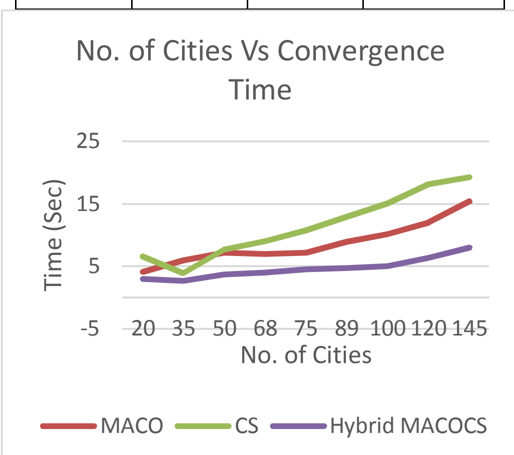

Fig.1

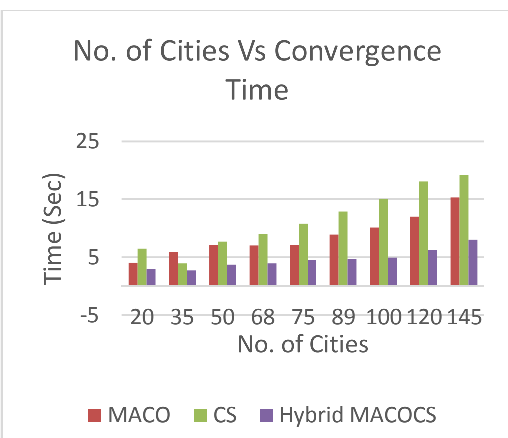

Fig.2

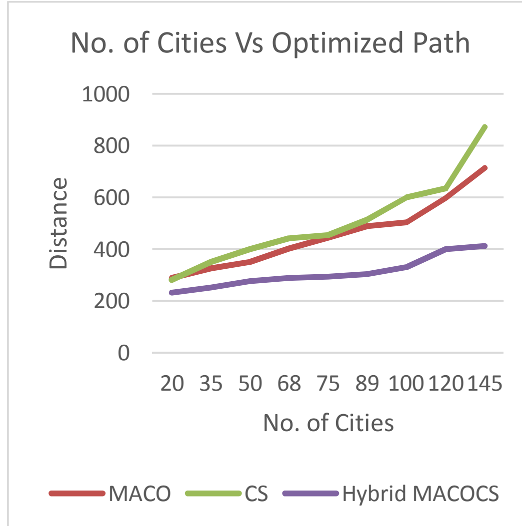

Fig.3

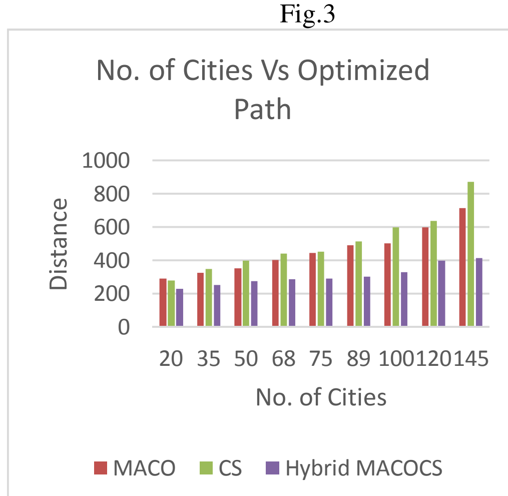

Fig.4

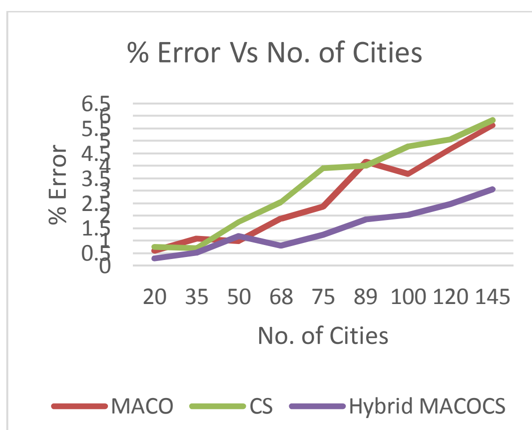

Fig.5

Table 4-percentage error occurred in all metaheuristic techniques

Number of city	MACO	CS	Hybrid MACOCS
20	0.61	0.75	0.29
35	1.08	0.69	0.51
50	0.98	1.75	1.18
68	1.89	2.55	0.79
75	2.37	3.91	1.23
89	4.15	4.01	1.86
100	3.68	4.77	2.03
120	4.68	5.05	2.48
145	5.62	5.82	3.05

7. Conclusion and Future Scope

In the proposed work motion planning of mobile robot is considered as an optimization problem. All three algorithms perform randomly search to find out feasible route by avoiding all hindrance coming in between the route without taking large computational time. It employs ACO as global path planning technique wile CS as local path planning.

From the simulation results, efficiency of proposed algorithm is verified and it can be concluded that by using hybrid MACOCS global optimal and real time obstacle avoidance can be achieved precisely. With each execution MACOCS give optimal solution as compared to other two techniques. It has also been identified that proposed hybrid algorithm can easily solve large scale complex optimization problems as compared to existing algorithms. In future, this study can be extended for considering the velocity with which dynamic obstacle is moving, and produce robust method. Forecasting of probability of collision for robot and obstacle can also be done in advance. Furthermore other types of nature inspired algorithms can be applied to such type of motion planning problems for optimization parameters.

References

1. Sapna Katiyar, Avneesh Mittal, A. Q. Ansari, T. K. Saxena, "Ant Colony Algorithm Based Adaptive PID Temperature Controller," Proc. 7th Int. Conf. on Trends in Industrial Measurements and Automation (TIMA 2011), CSIR, Chennai, January 2011.
2. O. Hachour, "Path planning of autonomous mobile robot", International Journal Syst. Appl. Eng., vol.4, pp. 178-190, 2008
3. Masehian, E. & Katebi, "Robot Motion planning in dynamic environment with mobile obstacles and target", International Journal of Mech. System Science Engineering, pp. 20-25, 2007.
4. Zhiye Li, Xiong Chen and Wendong Xiao, "A New Motion Planning Approach based on Artificial Potential Field in Unknown Environment", PDCAT, LNCS 3320, pp. 376-382, 2004.
5. Na Lv, Zuren F., "Numerical Potential Field and Ant Colony Optimization Based Path Planning in Dynamic Environment", IEEE WCI CA, pp. 8966-8970, 2006.
6. Zheng TG, Huan, H. & Aaron S, " Ant colony System Algorithm for Real Time Globally optimal path planning of mobile robots", Acta Automatica Sinica, vol. 33, pp. 279-285, 2007.
7. Dorigo. M. and Stutzle. T., "Ant Colony Optimization", MIT, 2004.
8. M. Dorigo and L.M. Gambardella, "Ant Colony System: a cooperative learning approach to the travelling salesman problem", IEEE Transaction on Evolutionary Computation, vol. 1, no. 1, pp. 53-66, 1997.
9. Ramin Rajabioun, "Cuckoo Optimization Algorithm", Applied Soft Computing, Elsevier, pp. 5508-5518, 2011.
10. Aziz Quaarab, Belaid Ahiod and Xin She Yang, "Discrete Cuckoo Search Algorithm for Travelling Salesman Problem", Springer Verlag London, vol. 24, pp. 1659-1669, 2014.
11. S. Deb, Xin She Yang, "Cuckoo Search via Levy Flights", World Congress on Nature & Biologically Inspired Computing, IEEE publications, pp. 210-214, 2009.
12. Abdesslem Layeb, "A Novel Quantum Inspired cuckoo search for knapsack problems", International Journal of Bio-Inspired Computation, vol. 3(5), pp. 297-305, 2011.
13. Momin Jamil and Hans Jurgen Zepernick, "Multimodal Functional Optimization with Cuckoo Search Algorithm", International Journal of Bio-Inspired Computation, vol. 5(2), pp. 73-83, 2013.
14. Mukul Joshi, Praveen Ranjan Srivastava, "Query Optimization: An Intelligent Hybrid approach using Cuckoo and Tabu search", International Journal of Intelligent Information Technologies (IJIIT), vol. 9(1), pp. 40-55, 2013.

15. A. Q. Ansari, Ibraheem, Sapna Katiyar, "Comparison and analysis of Obstacle Avoiding Path Planning of mobile robot by using ACO and TLBO", International Conference on Information and Communication Technology for Intelligent Systems, Springer (Smart Innovation, Systems and Technologies), vol. 51, pp. 563-574, 2015.
16. A. Q. Ansari, Ibraheem, Sapna Katiyar, "Comparison and analysis of solving travelling salesman problem using GA, ACO and hybrid of ACO with GA and CS", 2015 IEEE Workshop on Computational Intelligence: Theories, Applications and Future Directions (WCI), pp. 1-5, 2015.