An Improved ABC Algorithm for Optimal Path Planning

Priyanka Goel[1], Devendra Singh[2]

[1]Department of Computer Science & Information Technology, Moradabad Institute of Technology, Ram Ganga Vihar, Phase-II Moradabad, Uttar Pradesh, India

[2]School of Computer Engineering and Applications, Department of Computer Science, IFTM University, Lodhipur Rajput, Delhi Road (NH-24), Moradabad, Uttar Pradesh, India

Abstract: ***This paper presents an improved algorithm for path planning using Artificial Bee Colony Algorithm. This algorithm is used to find collision free shortest path from the start position to destination. The environment considered here is a two dimensional space consisting of both static and dynamic obstacles. The ABC algorithm used is inspired by the collective behavior of bees to find better food sources around the hive .The path generated by the original algorithm may be shorter but may not be optimized. So, the final path is optimized using triangle inequality method.***

Keywords: path planning, obstacles, collision, Artificial Bee Colony Algorithm, shortest paths

1. Introduction

Today robotics has emerged as a rapidly growing technique that includes research, design and construction of robots. The goal of an autonomous robot is to construct a map of the environment in which it is placed and to localize its position. Thus these should be intelligent and should be capable of determining their actions. The main focus is to make autonomous robots self sufficient while imitating human nature. Thus the designing of robots is very intensive task. Moreover the environment complexity is a specific problem due to its vastness, imprecise and changing nature. The autonomous robots should be capable of recognition, learning and decision making.

Path planning is an important issue in the field of robotics. It is a method to find collision free path from the start location to target location, given an environment consisting of obstacles. The path should be optimized using some reasonable algorithm where the optimization criteria can be time, distance or energy depending on the problem [1].

Path planning can be done in known or unknown environment. It is very difficult task to obtain path in unknown environment since the map of the environment is not certain. Though robots are employed with sensors and global positioning system but due to uncertainty it is not a feasible idea to have detailed plan beforehand. Path planning techniques can be categorized as- classical approaches and intelligent approaches.

Classical approaches include visibility graphs, voronoi diagrams, artificial potential field methods and quad trees. These approaches had certain limitations such as inefficiency in solving larger scale combinatorial and/or highly non-linear problems and their inflexibility to adapt the solution algorithm to a given problem. Generally a given problem is modeled in such a way that a classical algorithm has to make several assumptions which might not be easy to validate in many situations. so, the interest of the scientific community switched to the intelligent techniques such as Genetic algorithms, swarm intelligence approaches. Many of the researchers are inspired by the nature to develop new algorithmic models to solve problems especially in the field of optimization.

A branch of nature inspired algorithms which are known as swarm intelligence are focused on insect behavior so as to develop some meta-heuristics which can imitate the way insects used to solve their problems. Bonabeau has defined swarm intelligence as any attempt to design algorithms or distributed problem solving devices inspired by the collective behavior of social insect colonies and other animal societies [2]. Swarm intelligence consists of many algorithms such as ant colony optimization, particle swarm optimization, wasp nets and fish schools.

2. Literature Survey

Artificial Bee Colony optimization is a population based optimization technique which was first introduced by Karaboga in 2005. It is an algorithmic model to imitate the foraging behavior of bees to solve unconstrained optimization problems with continuous valued domains [3].

In late spring or early summers, bees divide themselves by a process of swarming. This is a process in which the queen and about half the worker bees leave their hive to establish a new colony. Meanwhile a daughter queen and the remaining of the worker bees live in the old hive. When the swarm of bees leaves its parental hive, the bees unite themselves, live on a nearby tree branch and continue searching for a new home.

Bees form colonies that extend over very long distances and in multiple directions in order to exploit food sources. The flower patches containing large amount of nectar that can be extracted with minimum difficulty are visited by most of the bees while the nectar sources with less amount of nectar are discarded. The foraging process begins by scout bees which are sent to collect nectar. The search starts randomly by the scout bees from one patch to another. When the scout bees reach to the hive, they deposit the amount collected and go to the dance floor to perform waggle ‘dance. This type of dance is the sole medium of communicating the information about the most promising nectar source to all other bees in the hive. This mysterious dance contains three pieces of information about flower patch: direction in which it is found, distance from the hive and the quality of nectar. When the food source exists at a distance less than 50 meters, then the scout bees perform round dance. On the other hand, if the food source exists at a distance greater than 50 meters, then the bees perform waggle dance.

After watching the waggle dance, unemployed bees (onlooker bees) follow the scout bee to the promising nectar source to collect nectar. This process helps all the bees to collect nectar in efficient and faster way. The quality of food source is continuously monitored by the bees so as to propagate this information in the next waggle dance.

3. Previous work

Savsani and Jhala[4] proposed an algorithm for path planning of a robot using artificial bee colony algorithm. The objective of the proposed algorithm was to minimize the travelling time and space. Saffari and Mahjoob [5] proposed a bee colony algorithm for optimal path planning of mobile robots. The algorithm works in two steps: Determining initial collision free path from the starting position to the target position and then optimizing the obtained path using bee colony algorithm. This was achieved by applying the technique of elitism. Lin and Huang [6] proposed an algorithm based on artificial bee colony and hybridized with chaos so as to improve global convergence.

Chia, Su, Guo and Chung [7] proposed an ant colony based mobile robot path planning. It attempts to reach the target position using the ant colony optimization and control the motion of the robot moving to the target position. Nagib and Gharieb [8] presented a new algorithm for path planning of mobile robot using Genetic Algorithm. This algorithm works on the basis that the robot passes from a specific point only once and not at all time. The ABC algorithm uses the concept of path integration. The present location is computed from past trajectory continuously. This algorithm consists of fewer control parameters as compared to GA, PSO and DE. This algorithm is robust and has faster convergence rate as compared to other algorithms. This algorithm is developed by inspecting the behavior of the bees in nature. The natural bees search better food source with respect to the amount of the nectar present in it and then share this information with all other bees present in the hive. The basic ABC algorithm is presented as:

Initialize the food source positions: xi (i=1. . . SN) solutions are generated randomly in the range of parameters where SN is the number of food sources.

Each employed bee produces a new food source and exploits a better source. For each employed bee, a new source is produced using equation (1):

$$v_{ij} = x_{ij} + \varphi_{ij} (x_{ij} – x_{kj}) \quad (1)$$

where φ_{ij} is a real random number generated in the range [-1, 1], k is the index of the solution chosen randomly from the colony. The value of k is calculated using equation (2):

$$k=int(rand*SN)+1 \quad (2)$$

and j=(1………D) where D represents the dimension of the problem.

After generating v_i, the new solution is compared with x_i and better solution is exploited by the employed bee.

Each onlooker bee selects a new source based on its quality given by fitness value and generates a new solution using equation (1) and exploits a better solution. Better source can be found out using equation (3):

$$p_i=\frac{fit_i}{\sum_{j=1}^{SN} fit_j} \quad (3)$$

where fit_i is the fitness of solution x_i.

After all onlooker bees are assigned a food source, food source which cannot be improved after predetermined number of cycles is abandoned. The employed bee of the abandoned food source becomes scout bee and makes a random search for new food source, using equation (4):

$$x_{ij}=x_j^{min}+(x_j^{max}–x_j^{min})*rand \quad (4)$$

4. Problem Statement

The working environment for mobile robot is created in such a way that the robot can understand, extract the relevant information and analyze the related properties. It is developed as a two dimensional surface, divided into a number of grids. The side length of each grid is taken as a unit of length. Grids are categorized into two types: free grid (represented by black color) where the mobile robot can move and the obstacle grid (represented by white color) where the robot is restricted to move. The environment consists of static obstacles as well as dynamic obstacles. A virtual boundary is provided to the obstacles so as to keep minimum safety distance for the robot from the obstacles (shown in Figure1). The path planning problem can be defined as: “Given a mobile robot R which is free to move in two dimensional space V. The space consists of some obstacles (static as well as moving) O and their shapes and trajectories are known prior. Given a source position S and target position T, our objective is to find optimal path from S to T without any collision using improved artificial bee colony algorithm.” Following are the assumptions in the method used for path planning:

(i) Since we have added minimum safety distance to the size of obstacles, the physical dimensions of our mobile robot can be discarded and it is considered as point object.
(ii) The trajectory of dynamic obstacles is considered to be in horizontal and vertical direction only.
(iii) All the dynamic obstacles are assumed to move in equal and fixed speed.

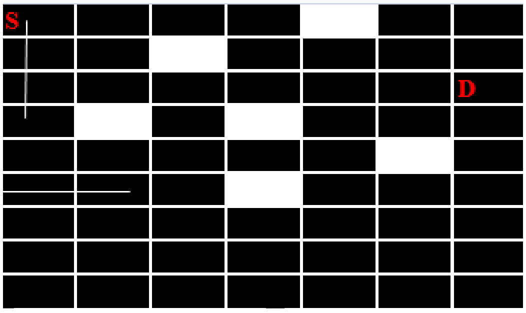

Figure 1: Snapshot of environment showing static and dynamic obstacles and source and destination positions

5. Improved ABC Algorithm

The procedure of improved artificial bee colony algorithm can be described as:

1. Generate the initial population of paths from the source node to the destination node.
2. Calculate the cost of each of the initial paths generated in step 1 using the following equation (5) :
   $F = dist + \beta * i$ (5)
   where F represents distance function, β represents the penalty of collision with the static obstacle and i indicates the number of static obstacles colliding.
3. Calculate the fitness value of each of the path generated as using equation (6):
   $fitness_i = 1/F_j$ (6)
   where j represents the path number whose fitness value is to be calculated.
4. Send employed bees to improve the path generated randomly.
5. If the fitness value of a particular path does not improve after certain limit of trials, it is abandoned.
6. Otherwise the best path is updated and its trial value is modified.
7. Calculate the cost of improved paths by considering the collision with dynamic obstacles as using equation(7):
   $F_d = F + \gamma * j$ (7)
   where γ represents the penalty of collision with dynamic obstacles and j denotes the number of dynamic obstacles colliding.
8. Arrange all the paths including improved paths in descending order of fitness value.
9. The path having high fitness value is expected to be selected for further improvement by onlooker bees.
10. If a particular path is not improved after certain trials, it is abandoned.
11. The employed bee of abandoned path becomes scout bee and starts a random search for better path.
12. Above process is repeated up to a predetermined number of cycles.
13. Apply triangle inequality method to further optimize the best updated path.

6. Simulation Results

To show the performance of proposed improved artificial bee colony algorithm, we have used the environment in the form of grid of 15 rows and 20 columns. Start location is at cell 0 and target location is at GridSize-1.We have used C programming language for path planning using improved bee colony algorithm. This code has been performed on a 2.24 GHz processor with 128 MB RAM. Figure 2 shows the performance comparison of performance original ABC algorithm and proposed IABC algorithm.

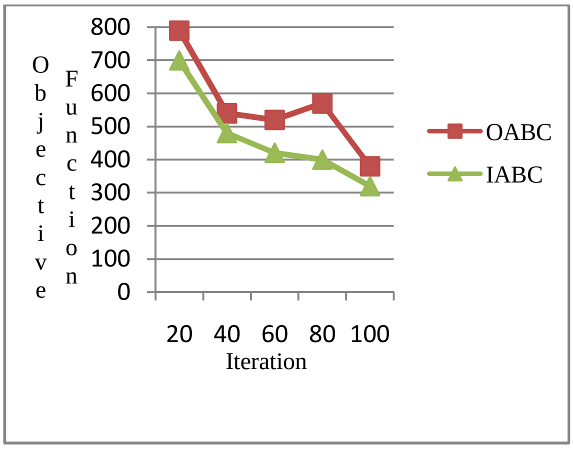

Figure 2: Comparison between Original ABC and proposed IABC algorithm on the basis of number of iterations

7. Conclusion

This research work developed and implemented an improved artificial bee colony algorithm for path planning by mobile robot in dynamic environment. The technique of triangle inequality generates final optimized paths. The results obtained show improvement of about 17% in generating shorter paths.

8. Future Work

The improved artificial bee colony algorithm solves the issues of path planning in dynamic environment; some work is still expected to be done in future. More realistic environment can be used to implement the proposed algorithm. This project works on two dimensional environment and the trajectories of the dynamic obstacles are defined to be straight line segments. The future work may consider three dimensional environment and the trajectories of dynamic obstacles can be curved. Sensors can be used to obtain the information related to the environment, the motion of dynamic obstacles and the location of the static obstacles.

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Author Profile

Priyanka Goel received the B.Tech degree in Computer Science and Engineering from Moradabad Institute of Technology in 2010. She started her career in teaching and joined Maharaja Agrasen College of Engineering and Technology in 2010. After 2 years of service in MACET, she joined Moradabad Institute of Technology, Moradabad in 2012 and is currently working there as Assistant Professor in CS & IT Department.

Devendra Singh received his B.Tech, and M.Tech degrees from RKGEC, Meerut in 2005 and Punjab Engineering College in 2009 respectively. He is pursuing PhD from IFTM University and is working as Assistant Professor in Department of Computer Science, School of Computer Applications and Engineering, IFTM University, Moradabad since 2005.