Autonomous Robot Path Planning in Static and Dynamic Environment by Applying Nature Inspired Computing (NIC) Algorithm

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Abstract: The mobile robot path planning is a central problem in several areas such as modern industry and cyber physical systems. This requires an embedding intelligence into that robotics for ensuring feasible solutions to task execution. Most of Research Problems are solved by observing the nature to solve our real-life day-to-day problems. The logic behind computing algorithms is inspired by nature for solving idea of computations problems. These algorithms are best optimization problems to solve computational problems in a reasonable time and providing optimum results. Path planning is one of the tasks of mobile robot to reach towards destination without any disturbance for reaching their goal within time bound. In this paper, the particle swarm optimization (PSO) is applied for mobile robot path planning to reach its destination. The performance results of proposed PSO for mobile robot path planning shows better results with conventional algorithms to reach destination with minimum energy consumption and also with minimize efficiency towards travelling from source to destination path.

Keywords: Nature inspired computing (NIC), particle swarm optimization (PSO), optimization, mobile robot, path planning

1. Introduction

Mobile path planning is a challenging task for mobile robots to reach destination by finding shortest distance path so as to optimize to minimize time, minimize energy consumption, maximize energy efficiency while reaching goal. The objective function (or fitness function) successfully to reach goal by optimize energy, time and cost. Particle swarm optimization is one of the swarm intelligence algorithms for optimization critical tasks. The swarm intelligence is one of the flavor of nature inspired computing algorithms for having feature of self-learning, self-motivation, communication with co-coordinately to fulfill tasks [1, 2, 3]. In this paper, particle swarm optimization algorithm is applied for free-collision path finding for mobile robot to reach destination from static as well as dynamic obstacles towards path.

The autonomous robots are smart machines for different tasks like goods handling, cleaning shops, transportation, monitoring, searching etc. Without human intervention these autonomous robots can solve these problems at a prescribed time. While robots are moving in a local environment it depends on two factors which are the environment will be either static or will be dynamic. In static environment, the environment structure will not change time to time. But whereas in dynamic environment the structure may change time to time. There are three tasks to fulfill by robot while selection of path between sources to destination they are no-collision of obstacle, minimize energy consumption, maximize efficiency, minimize time [4].

Classical methods are complex and not appropriate optimizations towards showing efficiency in robot movement for shortest path from source to destination. The nature inspired computing algorithms produces optimum results within reasonable amount of time. To implement robot path planning by applying popular nature inspired computing algorithms are ant colony optimization (ACO) [5], particle swarm optimization (PSO) [6]. In this paper swarm intelligence algorithm i.e., Particle swarm optimization (PSO) is applied for implementing static as well as dynamic technique for robot to find shortest path to reach towards destination [7].

Contribution of this paper is implement a nature inspired computing algorithm ie. Particle Swarm Optimization (PSO) to optimize the path planning for robot without collision with static as well as dynamic obstacles for getting optimum results.

Organization of this paper as follows- Section 2 introduction to particle swarm optimization (PSO) algorithm, Section3 literature survey of existing approach, in Section 4 proposed work methods, develop algorithms, in Section 5 results and discussion explanation for optimum results.

2. Introduction To Particle Swarm Optimization(Pso)

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995, inspired by social behavior of bird flocking or fish schooling.

Particle swarm optimization (PSO) is swarm intelligence technique. PSO is inspiration of flock of birds and fish schooling. Swarm intelligence is any problem for solving important is collective behavior is the only features to solve a problem efficiently.

Self-organization and division of labor are two properties of swarm intelligence. PSO is a meta-heuristic technique to optimize problems. Each particle has position & velocity associated. Each adjusting their position along with velocity.

By self-organization means the interactions are executed on the basis of purely local information without any relation to global pattern. Self-organization consists of positive negative and fluctuations. By division of labour i.e. the task performed simultaneously by specialized individuals. This constitutes as swarm intelligence.

PSO is a meta-heuristic technique to solve optimization problem, especially the problem the linear, non-linear or mixed integer or even our problem is a block optimization problem. The solution in optimization known as particular or bird in swarm intelligence. Each particle or bird has position and velocity associated. In real life particles keep change their positions by adjusting their velocity. Do this either to seek food or avoid predators or identify environmental parameters. There are many reasons particles change their positions. Each particle keep track their best positions identify it. So all particles communicate their own best location and from this best location. The individual particles modified flying experience of that particle. Velocity is modified flying experience of that particular particle position and velocity of particles. In 1st step is to initialize within the search space similar.
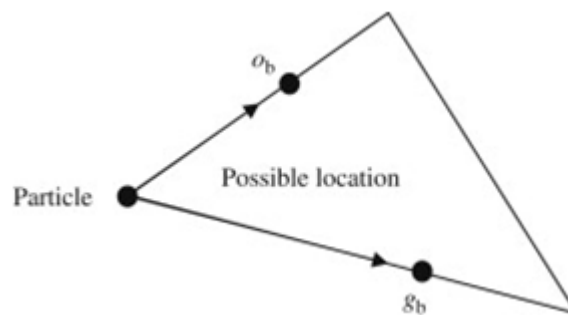

Fig1- Particle p_{best} (personnel best) and g_{best} (global best)

Particle Swarm Optimization (PSO) algorithm

[x*] = PSO()

P = Particle_Initialization();

For *i*=1 to *it_max*

     For each particle *p* in *P* do

fp = f(*p*);

       If *fp* is better than f(*pBest*)

         pBest = *p*;

       end

     end

gBest = best *p* in *P*;

     For each particle *p* in *P* do

v = *v* + *c1*rand*(pBest – p) + c2*rand*(gBest – p)*;

p   =   *p*   +   *v*;
   end
end

Particle update rule

    p = p + v

    with

$v = v + c_1 * rand * (pBest - p) + c_2 * rand * (gBest - p)$

where

p = particle's position

v = path direction

c_1= weight of local information

c_2= weight of global information

$pBest$= best position of the particle

$gBest$= best position of the swarm

$rand$ = random variable

3.   Literature Survey

In [8] proposed nature inspired computing algorithm i.e. particle swarm optimization algorithm for solving shortest path finding for robot towards destination. This paper is showing inefficiency not taken appropriate decision robot for moving its destination

In [9] proposed shortest path by using roadmap method (PRM) by applying particle swarm optimization algorithm. Authors use random nodes and apply with dijkstra's algorithm to reach shortest path for destination.

In [10] authors proposed nature inspired computing algorithm for robot movement towards destination goal by applying particle swarm optimization.

In [11] authors proposed optimum shortest path for robot towards to reach destination. Authors concentrate on population size to increase time to reach optimum results.

In [12] authors proposed enhance the balancing approach of exploration as well as exploitation by applying ABC algorithm. ABC perform better results for solve for problem of robot path planning

4.   Proposed Work

Particle swarm optimization applies for shortest path planning robot in-order to reach its destination without collision. In this we applied accumulated Euclidian distance method between autonomous robot and particle and target as objective function.

The inertia weight w is calculated for path planning.

$$inertiaweight = inertiaweight_{begin} - \frac{inertiaweight_{begin} - inertiaweight_{end}}{Max_{iter}} x Cur_{iter}$$

In above function Max_{iter} is maximum no. of iterations, Cur_{iter} is the current iteration, $inertiaweight_{begin}$ and $inertiaweight_{end}$ isinertiaweight starting and ending points. By applying linear decreasing of inertia value, particle swarm optimization to reach shortest path for robot to reach its optimum goal[13].

Particle swarm optimization (PSO) for path planning for static and dynamic moving particles environment [14]. Some constraints and limitations have been applied for path planning approach on robot. These are as follows.

i) The position of the robot must be shown in x, y, z directions and also the present position will visible to know. ii) Robot velocity is can be modify as per the next step iii) Robot must be in limits of the speed and will not move faster than that of specifying speed limits iv) Robot will sensing these nearby area where robot is moving in a search space. Because robot can identify if any other obstacles like other robots, things in its path automatically change its path not to collide with these things.v) Robot must identified its position and decide to where to move towards path as per applying algorithm.

i) Objective Function

The important objective of our paper is evaluating the particle's position in search space and selects the autonomous robot move next position and the best position towards direction of a destination path to reach its optimum goal by applying nature inspired computing algorithm i.e, PSO. The objective function applies for Euclidean distance between current particle's position as well as destination (goal) position. And also describes about distance from particle's position and robot's position as following formula.

$$F(n) = \sqrt{(x_{particle} - x_{robotics})^2 + (y_{particle} - y_{robotics})^2} +$$

$$\sqrt{(x_{particle} - x_{goal})^2 + (y_{particle} - y_{goal})^2}$$

In the above equation f(n) is fitness function (i.e. objective function). $x_{particle}$, $y_{particle}$ are the particle positions, $x_{rorobitcs}$, $y_{robotics}$ are the robotics positions and robot reach towards shortest path destination goal is x_{goal} , y_{goal}.

ii) Design of the algorithm

To find next position of robot the following steps are very important to note.

step1- In particle swarm optimization(pso) particles are randomly move from robot current_position within searching space.

step2- Every particle must in search_space for moving towards destination, while moving towards path if any obstacle found in certain path robot able to sense this obstacle.

step3- every particle must update position and velocity as per particle swarm optimization.

step4 - If any obstacle found in robot path than automatically avoid position move as per step3.

step5 - The best position of robot update as per maximum iterations done by robot.

step6 - until robot reach the destination repeat steps from 1 - 5.

Virtual environment for moving robot in a search space covers 100x100 unity units. The obstacles randomly placed in this search space. These obstacles are either wall shapes or square shape or oval shape available.

Table 1 describe parameters for swam particle optimization while executing.

Table 1: PSO Parameters

Size of swarm	20
Dimensions information	2
Max. iterations	100
C1 (cognitive parameter)	2
C2(social parameter)	2
C (constriction factor)	1
Inertia start	0.9
Inertia end	0.4
Optimization variables higher limit	10
Optimization variables lower limit	-10

In Table2, information is given about scenarios of simulation. Fig 1 shows single particle obstacle by moving its path by moving towards destination. Fig 2 shows wall following path movement with one static obstacle and also added more static obstacles in path of robot movement. Fig 3 with added dynamic different shapes of obstacles in a search space. Also it shows more complicated robot movement to reach its destination in search space. Authors added more complex obstacles for test efficiency of robot moving towards destination without any collision, minimize time, minimize energy consumption and maximize energy efficiency.

Table 2 Difference between performance results for path covering distance & time by PSO and newly proposed PSO

Table 2: Information about scenarios of simulation

Fig. No.	Path length reached by robot (In pixels)	Duration need for robot to reach destination (in seconds)
	PSO	PSO

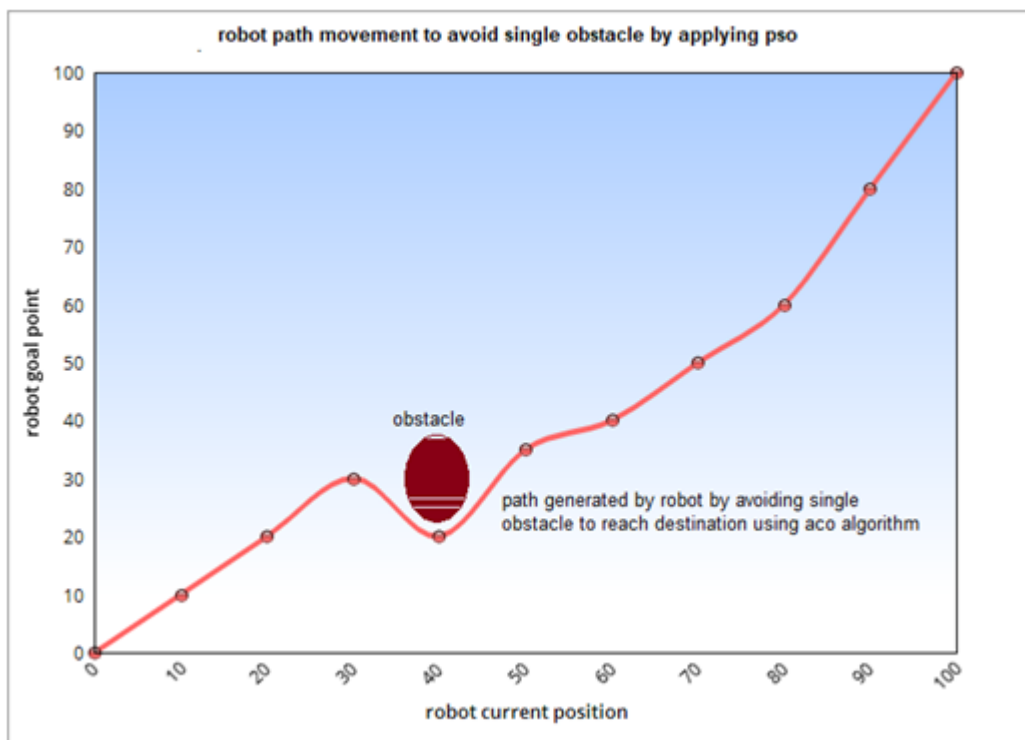| Fig2	420.17	3.300
Fig3	445.20	3.500
Fig4	610.12	6.300
Fig5	475.35	4.300

5.   Results And Discussion

Fig1- Single obstacle avoidance using PSO

The above Figure 1, the graph having x-axis (showing robot current position) and y-axis (showing robot goal point). Without collision of a single obstacle (static) in a path, the robot choose shortest path for its destination.
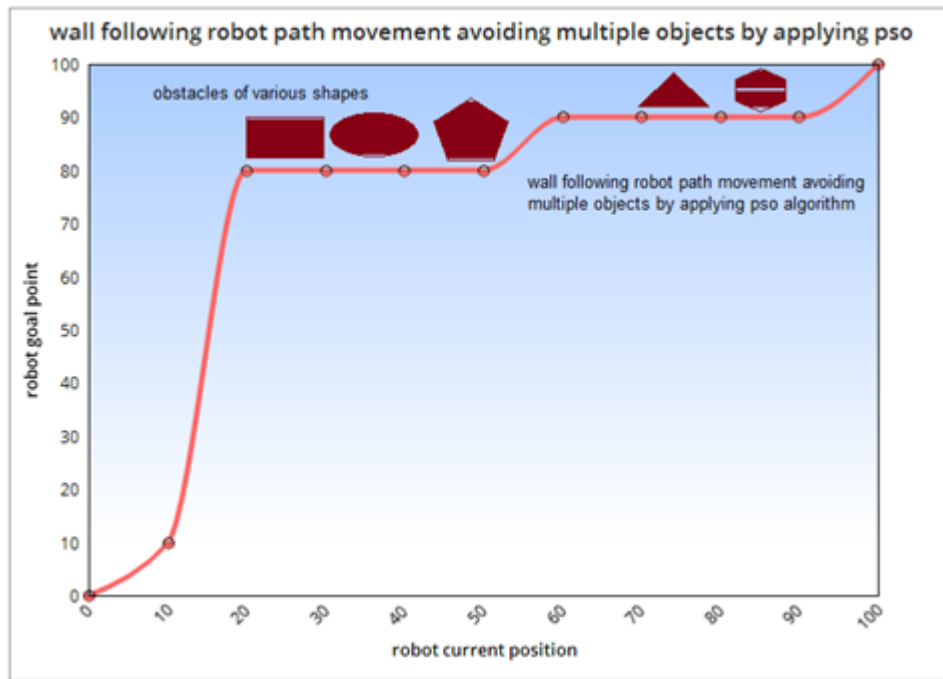
Fig2- Wall following path movement using PSO

The above Figure 2, the graph having x-axis (showing robot current position) and y-axis (showing robot goal point). Without collision of a various shapes of multiple obstacles (static) in a path, the robot choose shortest path for its destination by applying PSO algorithm.
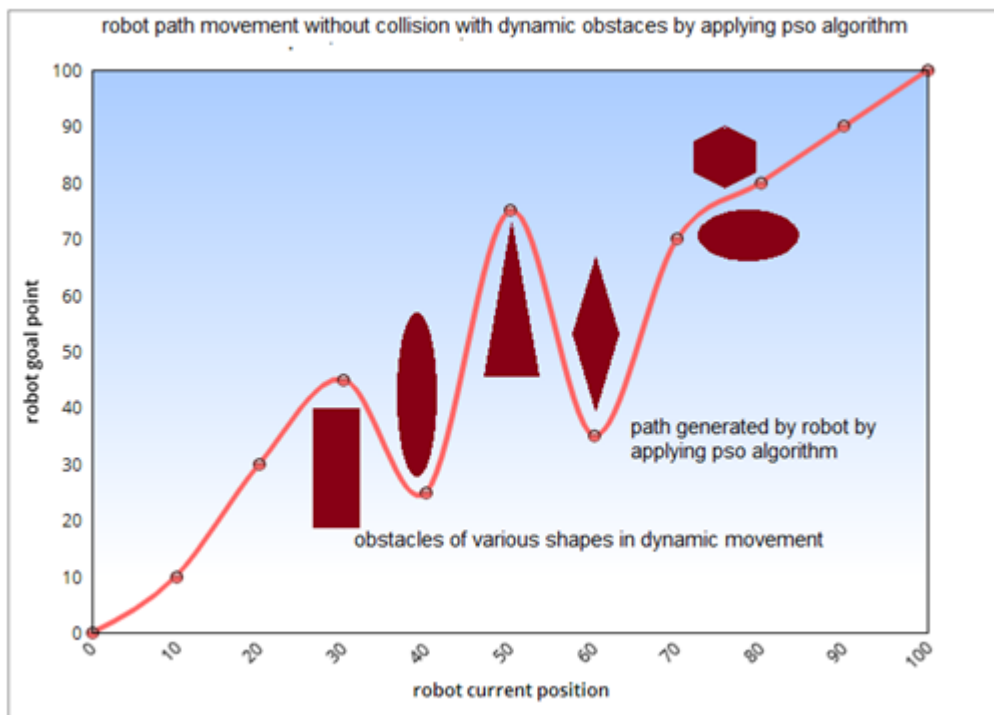

Fig3- robot path movement without collision with multiple dynamic various shapes of obstacle by applying PSO algorithm

The above Figure 3, the graph having x-axis (showing robot current position) and y-axis (showing robot goal point). Without collision of a various shapes of multiple obstacles (dynamic) in a path, the robot choose shortest path for its destination by applying PSO algorithm.

6.   Conclusions

Authors discussed about implementation of robot to find shortest path towards its destination. This paper mainly addressed robot routing to reach destination with static and dynamic obstacles without collisions. Authors implemented using PSO algorithms for robot movements either statically and dynamically to reach its destination without collisions in search area. The results such as Single obstacle avoidance, Wall following path movement and multiple dynamic various shapes of obstacle using PSO algorithms are presented. The performance results of proposed PSO for mobile robot path planning shows better results with conventional algorithms to reach destination with minimum energy consumption and also minimize efficiency towards travelling from source to destination path.

7.   Acknowledgement

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