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[COTII- 2018]

ISSN 2348 – 8034
Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

CONTROL OF AUTOMATED ROBOT MOTION UNDER DYNAMIC ENVIRONMENT

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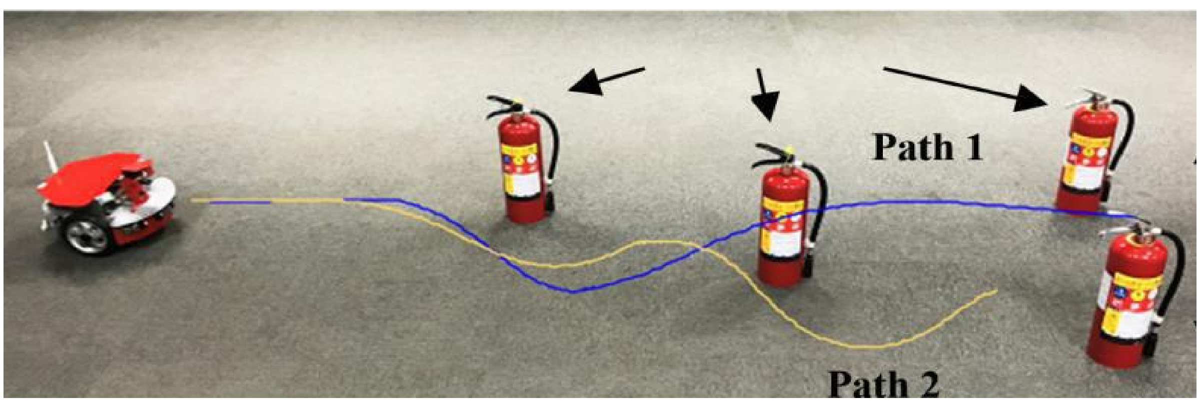
ABSTRACT

It had been a great challenge for researchers from decades that navigation of autonomous robot motion. The Control and navigation of robot motion in unknown environment is burning topic in the field of robotics. The major problem in robot navigation includes features as to detect and avoid the obstacles in the environment, smooth travel and reaching at a particular defined position. Among these the obstacle avoidance part is of main importance in robot navigation problem. The robots will only avoid the collision with objects if it has the ability to sense the obstacles in its path take decisions and move away from an obstacle that means the robot should be intelligent and it can be achieved through programming. Here the main goal is to design and develop intelligent robot motions for autonomous navigation under dynamic environment. At the same time it will add more complexity and difficulty in controlling all the robot motions. The obstacle avoidance issue of multiple robot motions in unknown dynamic environment is addressed in this paper. For better motion control and obstacle avoidance PSO algorithm is used.

Keywords: *Robot motion, Navigation, Obstacle Avoidance, Dynamic Environment, PSO (Particle Swarm Optimization) algorithm.*

I. INTRODUCTION

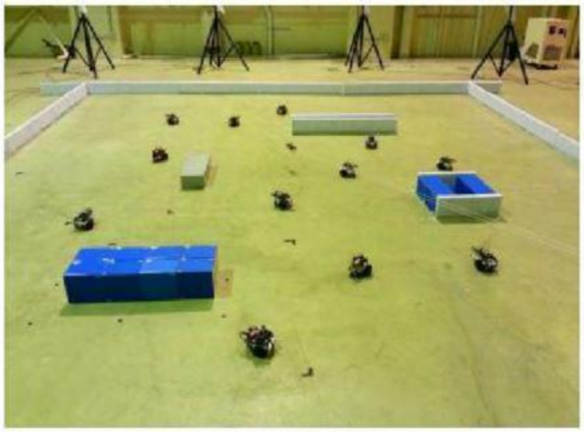
The motion planning of mobile robots is of paramount interest in the field of Robotics. Automation navigation of robotic vehicles saves unnecessary wastage of time and money. A lot of path planning algorithms are proposed by various researchers in the past. Some of the popular methods like the Fuzzy Logic, neural network, genetic algorithm, and visibility graphs and so on. Among these popular algorithms Particle Swarm Optimization (PSO) is one of the most popular algorithm for its simplicity and better convergence**.**

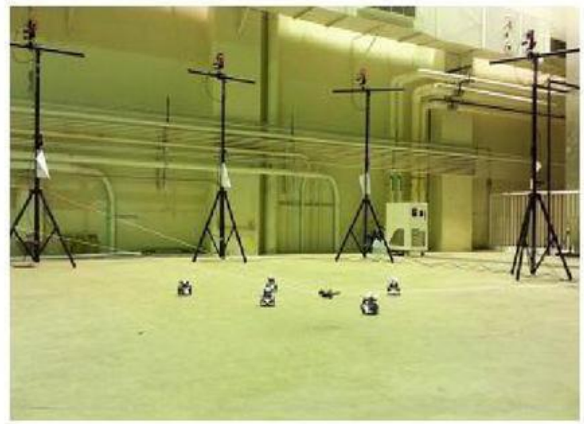


1. Implementation of Particle Swarm Optimization (PSO) in multi-robot cooperation:

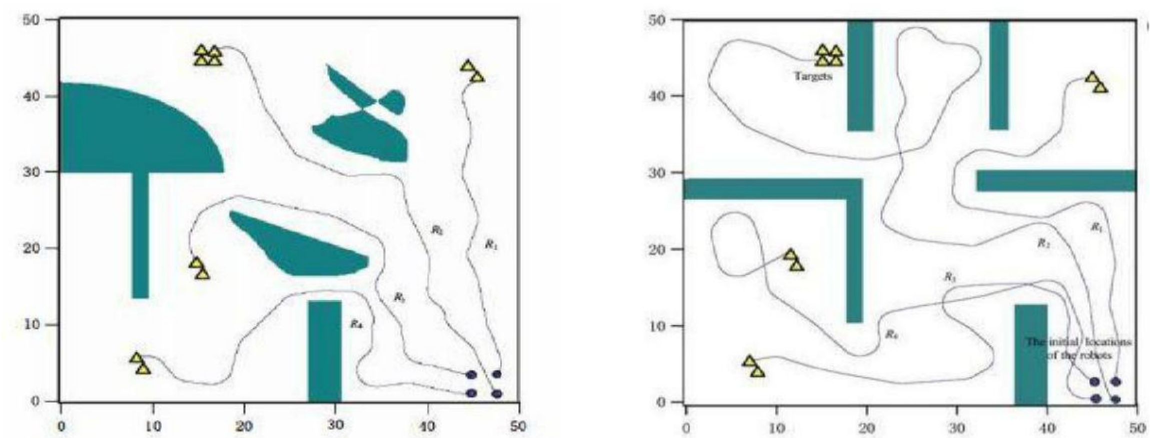
Identifying the source of signal in dynamic cluttered environment is one of the most challenging and complex problem. The complexity becomes more due to randomness and interference of noise in the environment. Source seeking behaviour of swarm of mobile robots using Particle Swarm Optimization is described. Apart from this the obstacle avoidance nature of mobile robot is also discussed in this paper.

Any kind of signal such as acoustic signal, thermal signal, electromagnetic signal or chemical signal may be the source but in this research article electromagnetic source signal is considered.


Robots with obstacles in the area


Robots approaching source

Any kind of signal such as acoustic signal, thermal signal, electromagnetic signal or chemical signal may be the source but in this research article electromagnetic source signal is considered. The experiment is carried out indoor and Vicon tracking system is used for getting the information regarding position of the mobile robots.



multi robot navigation with irregular and structured obstacles

2. Motion planning of mobile robot using Particle Swarm Optimization (PSO) and its variants:
Mobile robots can be used for surveillance and infiltration detection. Hence fast movement of mobile robot with smooth obstacle avoidance is an important topic.

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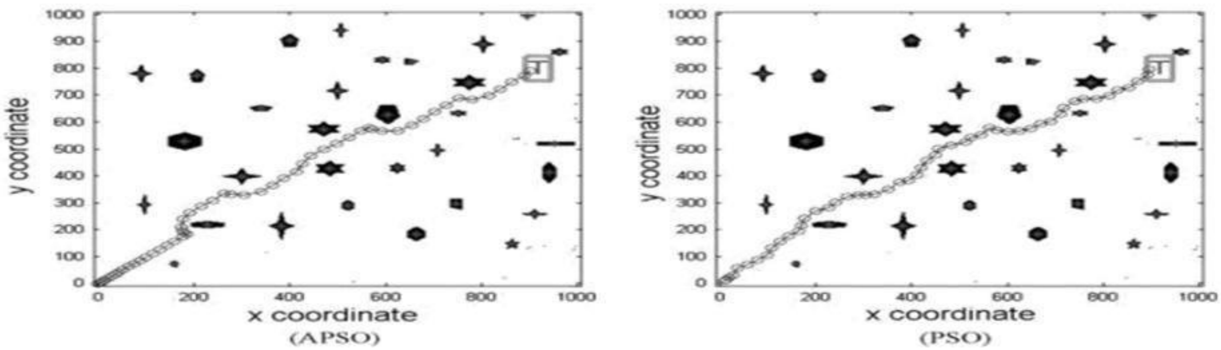
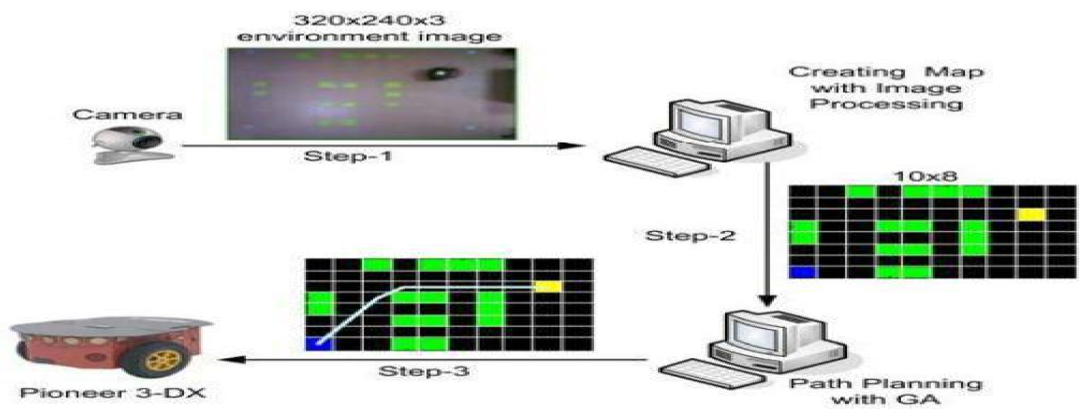


Fig. comparison of paths generated by PSO and APSO

The position and velocity equation of PSO is modified and merged to a single equation to enhance the speed of the process. The process is simulated for both static and dynamic obstacles that mean the obstacles whose position changes with time. The comparison of PSO and APSO (Accelerated PSO) is performed.

3. Path Planning Of Mobile Robot Using Genetic Algorithm

Adem et. Al [8] proposed motion planning of mobile robot using Genetic Algorithm (GA).Camera is used for locating the positions of mobile robot, target and obstacle.



Motion planning system of mobile robot

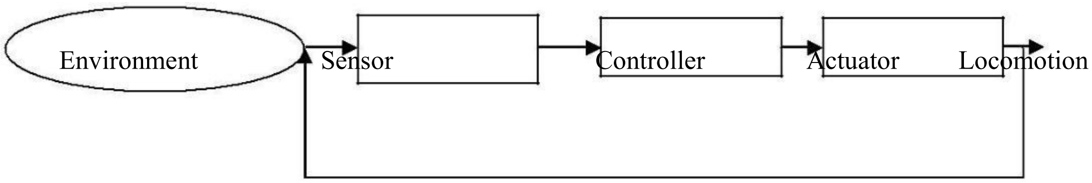
A graphical user interface (GUI) was developed for user interaction with robotic system. For performing the experiment the Pioneer P3-DX mobile robot is used.

4. Mechanical system architecture for mobile robot

System architecture of mobile robot basically refers to the integration of both software and hardware for control and navigation of robot. The software part of this includes the autonomous control of the mobile robot through programming whereas the hardware part includes various sensors, actuators for perception, locomotion and task performance. Moreover, we can say that the software part of the architecture is similar to human brain, which takes the decision and the hardware part is nothing but the combination of sensory organs, limbs used for sensation of surrounding and locomotion.

4.1. Mobile Robot Positioning

The mobile robot is having different parts or assemblies such as a sensor module for perception, an actuator module for movement, control unit or the controller for motion control. In this research paper, the considered mobile robots have two wheels connected with two DC geared motors, one castor wheel, one servo motor and one ultrasonic sensor. The considered robots are differential wheeled robots which mean the manoeuvrability of these mobile robots depends on the relative motion between two wheels placed on either side of the robotic platform. Thus the robots can accordingly alter their course of movement by differing the relative rate of movement of their wheels and henceforth does not require an extra guiding movement. The whole process of motion control of mobile robot is a closed loop process which can be shown as follows:



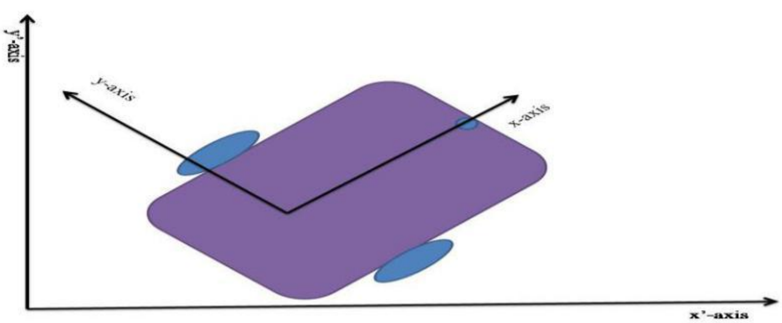
Closed loop structure of mobile robot architecture

Let us consider a robot moving in a plane. The position of the robot can be represented by establishing the relation between the global and local frame of reference. The robot can be represented as a point with co-ordinates (x, y) in 2D. The movement of the robot from one point to another point can be represented as follows:

Translation Equation:
The translation of a point from one position (x, y) to another position (x', y') can be done as follows:

$$x' = x + \quad x \qquad (3.1)$$

$$y' = y + \quad y \qquad (3.2)$$



Rotation Equation:
The rotation of a point or a line from a position (x, y) to another position (x', y') by an angle α can be done as follows:

$$x' = x * \cos(\alpha) + y * \sin(\alpha) \qquad (3.3)$$

$$y' = -x * \sin(\alpha) + y * \cos(\alpha) \qquad (3.4)$$

4.2. Range Sensor module specification
The sensor which is considered in this project is ultrasonic sensor HC-SR04. It determines the distance of the object like the way bats and dolphins do.

Fig. Arduino Mega 2560 board

Table Specification of Arduino Mega 2560-

Microcontroller	**ATmega2560**
Operating Voltage	**5V**
Input Voltage (recommended)	**7-12V**
Input Voltage (limits)	**6-20V**
Digital I/O Pins	**54 (of which 15 provide PWM output)**
Analog Input Pins	**16**
DC Current per I/O Pin	**40 mA**
DC Current for 3.3V Pin	**50 mA**
Flash Memory	**256 KB of which 8 KB used by bootloader**
SRAM	**8 KB**
EEPROM	**4 KB**
CLOCK SPEED	**16MHz**

The interfacing of ultrasonic sensor is performed to find the distance of objects and it gave accurate results. Control of a servo motor is done using Arduino and two DC geared motors also interfaced with Arduino. Control of motor as per the data received from the ultrasonic sensor is done.

5. Actuators for locomotion

Servo motors are the motors which rotate to a particular angular position. It works on the principle of closed loop servo mechanism. It is generally a combination of four things such as a DC motor, a gearing set, a controller and a position sensor. Here instead of controlling the motor by applying variable input, the device is controlled by a feedback signal generated by comparing output signal and a reference signal.

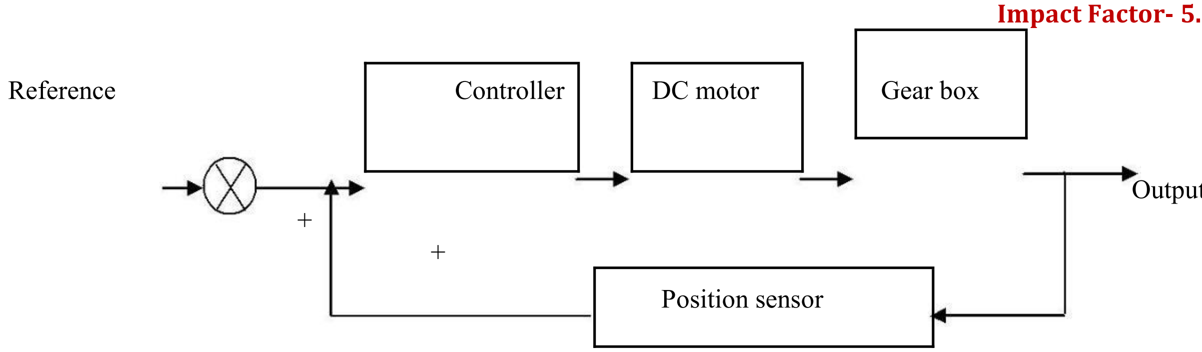


Fig. Servomechanism of position control

When input signal is given to the system the output signal is measured with a sensor and compared. The difference of the signal value is given to the controller which controls the
device in such a manner that the difference becomes zero. The feedback process continues unless the difference becomes zero.

The stepper motor is nothing but a servo motor which moves to a particular angular position through an equal number of finite steps.

To detect obstacles in front of the robot the ultrasonic sensor should capable of detecting obstacle full 180 degrees. Hence it is mounted on a servo motor and the motor is programmed to rotate up to 180 degrees.

6. Controller for Mobile Robot

The controller is the prime part which plays a vital role in any field of automation and control. Generally, all the tasks performed by the mobile robots are controlled by a microcontroller. There are different types of microcontroller available in the market. Some of the popular microcontrollers used in research are ATmega, PIC, 8051 etc. In this project, an open source hardware controller known as "Arduino" is used which uses the ATmega microcontroller

Arduino is an open source hardware assembly which uses an onboard ATmega microcontroller and programming is done using its open source IDE. There are some features of Arduino which made it popular such as inexpensive, cross-platform, simple programming environment, open source and extensible software, open source and extensible hardware, etc.

7. Mathematical representation of PSO Algo

The Particle Swarm Optimization technique is inspired by the social behaviour of birds and fishes. In the case of bird flocking, when birds move in a group then each bird in the flock is having its own position and velocity. This is nothing but the personal best position of each bird. The best position in the flock is gauged based on an input parameter known as objective function or fitness function. In case of bird flocking, the fitness function parameter is searching for food in less distance from the shelter for birds. So each bird is having some personal best position based on this fitness function. The position of the bird which has optimal fitness value is considered as the global best position. As the birds share information among them, all birds will tend to move towards the global best position.

As PSO is inspired by the social nature of bird flocking, each bird can be considered as one particle. So each particle has its own position and velocity. The position of the particle which satisfy optimum fitness value criterion is chosen as the global best position. Fig.1 below shows the structure of PSO.

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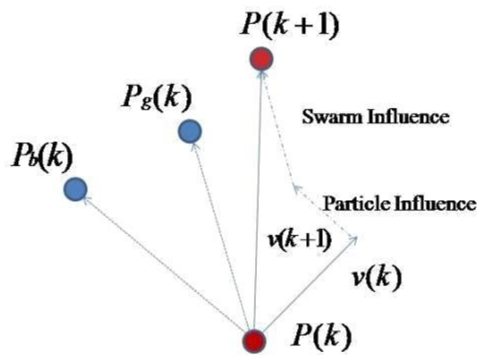

The mathematical equation of PSO is given below:

$V_i(k+1) = w^* V_i(k)+c_1{*}r_1(Y_{Pbest}-y_i)+ c_2{*}r_2(Y_{Gbest}-y_i)$ (4.1)

$y_i(k+1)= y_i(k)+ V_i(k+1)$ (4.2)

Where i = Particle Number.
k= Iteration counter.
w= Inertial weight (decreasing function).
c_1 and c_2 = Acceleration coefficients known as cognitive and social parameters.
r_1 and r_2 = Random values in [0,1].

Y_{Pbest} = Best position of particle.

Y_{Gbest} = Global best position of particle

8. Fitness Function Consideration

The fitness function is nothing but the set of boundary conditions or constraints to fulfill the control objective. In this paper a new fitness function is generated to get the desired result. The fitness function can be chosen like this-

1. The distance between the robot (particle) and destination should be as small as possible. Hence the fitness function should be directly proportional to distance between the robot and destination.

$F \alpha \Gamma R\text{-}GOAL$ (4.3)

Where F = fitness function.

$\Gamma_{R\text{-}GOAL}$ = distance between the robot and goal position.

2. The distance between the robot and obstacle should as large as desired. So the fitness function is inversely proportional to distance between the robot and obstacles.

$F \alpha 1/\Gamma R\text{-}OBSTACLE$ (4.4)

Where $\Gamma_{R\text{-}OBSTACLE}$ = distance between the robot and obstacles.

3. Similarly the distance between robots within its sensing range is large. Hence

$F \alpha 1/\Gamma_{R-R}$ (4.5)

Where Γ_{R-R} = distance between robot and robot which is a time varying function.

Now combining all the conditions the complete fitness function can be written like this

$$F \alpha \frac{\Gamma R\text{-}GOAL}{\Gamma R\text{-}OBSTACLE * \Gamma R\text{-}R} \quad (4.6)$$

Now

$$\Gamma R\text{-}GOAL = \sqrt{(R_{xi} - goal_x)^2 + (R_{yi} - goal_y)^2} \quad (4.7)$$

Where R_{xi} , R_{yi} are the robots (particles) positions and $goal_x$, $goal_y$ is goal position.

$$\Gamma R\text{-}OBSTACLE = \sqrt{(R_{xi} - O_{xi})^2 + (R_{yi} - O_{yi})^2} \quad (4.8)$$

Where O_{xi} , O_{yi} are the obstacles in the search space.

$\Gamma_{R-R} = \mu 1 * t * V_{R-R} + \mu_2 * \theta$

Where t = time in seconds.

V_{R-R} = relative velocity between two robots. For simplicity velocity of all the robots is taken same that is uniform but it can be taken different for different robot.
θ = angle of heading of robots.

From equation (6) we can write

F = ψ * $\Gamma_{R\text{-}GOAL}$ (4.10) ΓR-OBSTACLE *ΓR-R (4.9)

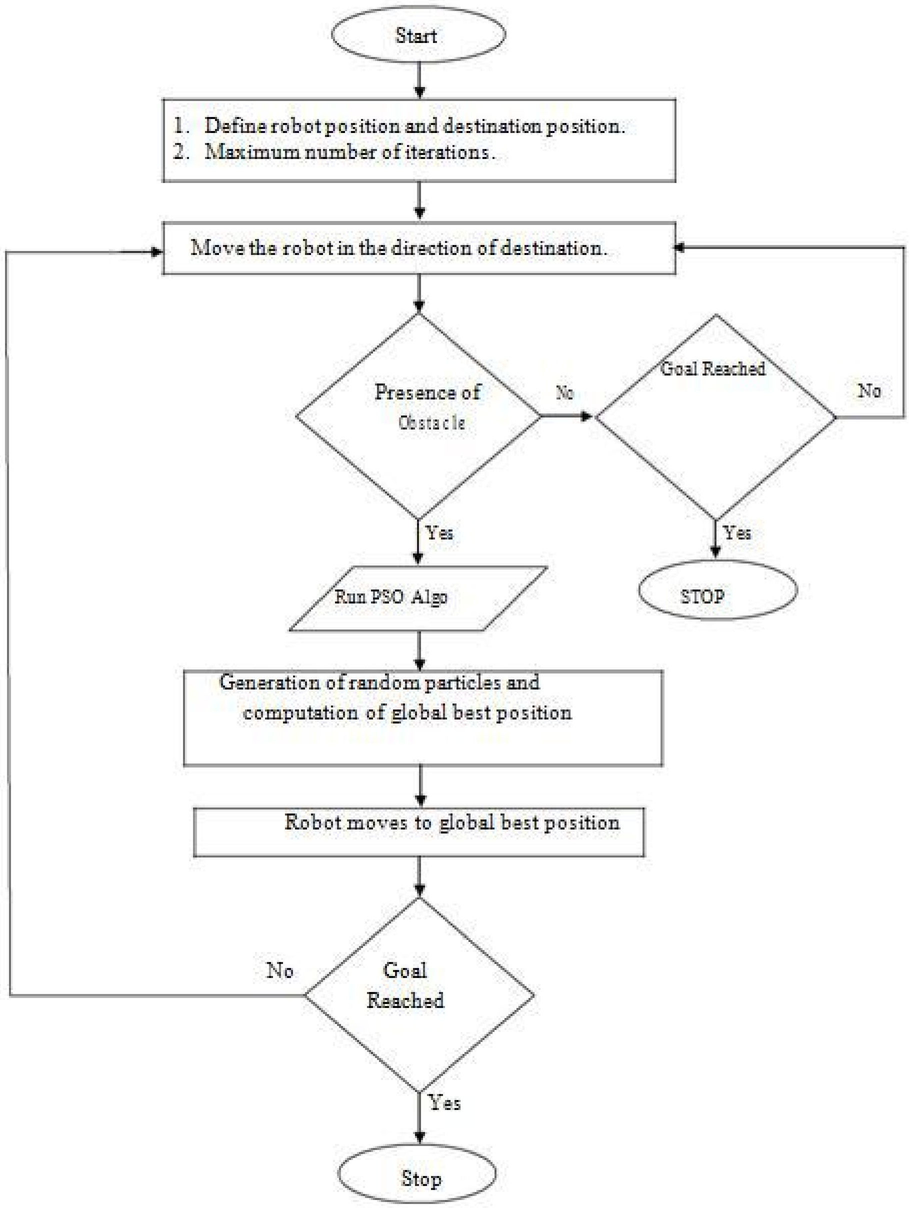

Fig. Flowchart of the Algorithm

The experimental analysis is performed in real time environment with three mobile robots. For better sensing of obstacles the ultrasonic sensor is mounted on a 0-180 degree rotatable servo motor. The robots are capable of detecting both static and dynamic obstacles. Static obstacles are non-mobile obstacles while dynamic obstacles are movable.

The detection of dynamic or mobile obstacles is major challenge compared to static obstacles. Because the position of the object changes with time in case of dynamic environment. In case of multi-robot cooperation one robot is

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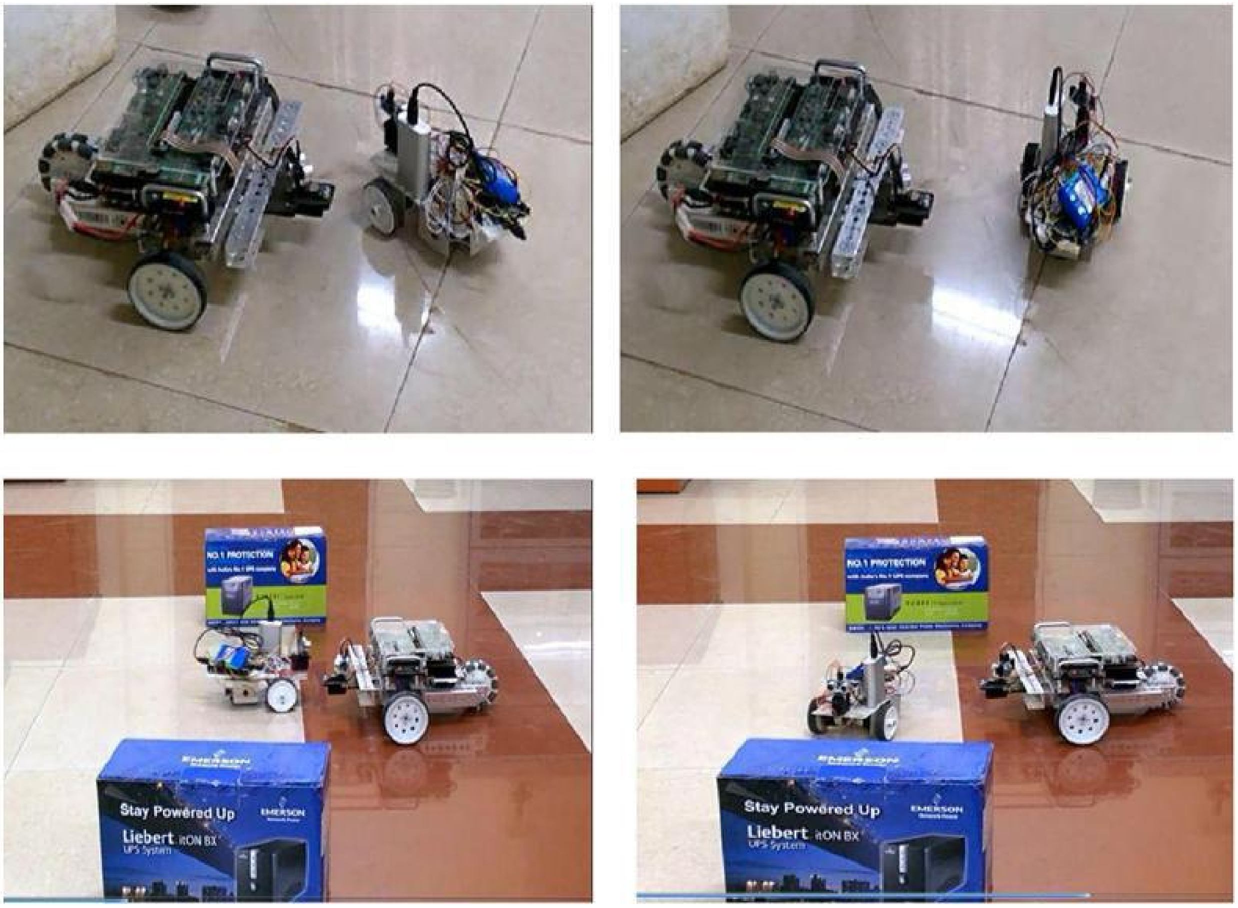
dynamic obstacle for another robot. So better calibration of ultrasonic sensor is necessary. The pictures showing avoidance of dynamic obstacles is given below



Multi robot cooperation is one of the flamboyant topics in the current age of robotics. The research dissertation mainly focuses on the autonomous navigation of the mobile robots. The excellent part of the project is that obstacle avoidance is performed using low cost Ultrasonic sensors and there is no use of advanced sensors like LASER, Stereo camera etc. The major problems are like smooth orientations, goal seeking of the robots etc. There are some design issues also like improper load distribution, improper differential orientation etc. The robots are tested in real time environment with static and dynamic obstacles. For complete 180 degree view of the robot in the forward movement direction the ultrasonic sensor is mounted on the servo motor. Proper control of the angle of the servo motor is necessary to move the ultrasonic sensor in the desired direction. At the same time accurate calibration of the ultrasonic sensor should be done to get the exact distance of the obstacle.

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