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A COMPARATIVE STUDY FOR WHEELED MOBILE ROBOT PATH PLANNING BASED ON MODIFIED INTELLIGENT ALGORITHMS

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ABSTRACT

From the time being, there are even instances for application of mobile robots in our life like in home, schools, hospitals, etc. The goal of this paper is to plan a path and minimizing the path lengths with obstacles avoidance for a mobile robot in static environment. In this work we depict the issue of off-line wheeled mobile robot (WMR) path planning, which best route for wheeled mobile robot from a start point to a target at a plane environment represented by 2-D work space. A modified optimization technique to solve the problem of path planning problem using particle swarm optimization (PSO) method is given. PSO is a swarm intelligence based stochastic optimization technique which imitate the social behavior of fish schooling or bird flocking, was applied to locate the optimum route for mobile robot so as to reach a target. Simulation results, which executed using MATLAB 2014 programming language, confirmed that the suggested algorithm outperforms the standard version of PSO algorithm with the same environment conditions by providing the shortest path for mobile robot.

KEYWORDS: Wheeled Mobile Robot, Path planning, Static Environment, and Particle Swarm Optimization Algorithm, Chaotic PSO.

دراسة مقارنة لتخطيط مسار الروبوت المتحرك بعجلات استنادا الى خوارزميات ذكية معدلة

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الخلاصة

في الوقت الحالي هنالك عدد من التطبيقات للروبوتات المتنقلة في حياتنا مثل المنزل والمدارس والمستشفيات، الخ. الهدف من هذا البحث هو التقليل من طول المسار وتجنب العوائق للروبوت المحمول في بيئة ثابتة. نعرض في هذا العمل مسألة تخطيط مسارا لروبوت متحرك ذا العجلات من نقطة البداية الى نقطة الهدف في بيئة مستوية ممثلة بمساحة عمل ثنائية الابعاد. تم حل مشكلة تخطيط المسار باستخدام طريقة تحسين سرب الطيور وهي تقنية الاستنتاج العشوائي المستندة الى ذكاء السرب والتي تقلد السلوك الاجتماعي للأسماك او الطيور تم تطبيقها لتحديد المسار الامثل للروبوت المتحرك للوصول الى الهدف. نتائج المحاكاة والتي تم التوصل اليها باستخدام لغة الماتلاب أكدت أن الخوارزمية المقترحة تتفوق على خوارزمية سرب الطيور القياسية مع نفس ظروف البيئة من خلال توفير أقصر مسار للروبوت المتحرك.

الكلمات المفتاحية: الروبوت المتحرك بعجلات، تخطيط المسار، البيئة الثابتة، خوارزمية سرب الطيور، خوارزمية سرب الطيور المشوشة .

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INTRODUCTION

In general, a large number of studies and articles count the wheeled mobile robots as a major subject of large benefit due to their evolutionary applications Al–Araji [2014]. Mobile robots have been successfully applied in many fields such as medical and military applications, space exploration, public and domestic duties. They can implement difficult and hazardous jobs with complex requirements and often have to do so autonomously, without the help of a human operator Cholodowicz, et.al,[2017]. Path planning is a significant issue in navigation of mobile robots. The goal is to detect a best and collision –free path from a source point to a destination point in a predefined work space. In any event, there are a number of routes for mobile robot to accomplish the goal, but actuality, the desired route is picked according to several optimization criteria. These optimization criteria are: shortest route length, least energy consuming or minimum time with the shortest route length is the most adopted criteria [Abbas, et.al, 2016]. The mobile robot path planning issue is commonly work out as describes: specified a wheeled mobile robot and definition of a work space, plan a route between two fixed positions, a source and goal point [Mnubi, 2016].The path planning environment can be classified into two main types : static and dynamic. In the static environment, the entire routes should be form before beginning pursuance. While, for dynamic environment, re-planning are wanted from time to time and additional update time is required .Respecting on the environment kind, path planning approaches are divided into two classes, which are online and offline techniques .They might also divided into conventional and soft computing techniques. Conventional path planning methods such as Artificial Potential Field (APF), Road map and Cell decomposition approaches. As to soft computing methods, they include Particle Swarm Optimization (PSO), Neural Networks (NNs), Ant Colony Optimization (ACO), Fuzzy Logic (FL) and Genetic Algorithms (GAs). Clearly, each algorithm has its own power points and flaw points which motivate investigators to treat options and more effective algorithms [Jalel, et.al, 2015]. The rest of this paper is ordered as follows: section 2 describes the related work; section 3 describes a model of wheeled mobile robot; section 4 describes the path planning problem; section 5 describes the classic PSO algorithm; section 6 describes the Chaotic PSO algorithm and simulation results and discussion are presented in section 7.Finally, section 8 gives the research conclusions.

RELATED WORKS

There are many kinds of research studies path planning in recent years. In 2014, N. H. Abbas et al, describes the use of directed Artificial Bee Colony algorithm to get the best route from start position to goal position in free-space environment. That research offers that the proposed algorithm is efficient and acquire routes with pleasurable products [Abbas, et.al, 2014]. In 2015, S. Jalel et al, introduced a new mobile robot path planning technique by using NURBS (Non Uniform Rational B-spline) curve designing using GA to perform the optimal route between start and goal points [Jalel, et.al, 2015]. In 2016, T. A. Jaleel et al, suggested a hybrid control methodology using improved APF with modified CSA to path planning of decentralized method for multi mobile robot in moving environment. Simulation results offer that the suggested technique lack to locate an entire, optimum and collision -free path for multi mobile robot [Jaleel, et.al, 2016]. In 2015 A. A. Ahmed et al, performed path planning in unknown environment by combining APF approach with Fuzzy Logic Control (FLC) to think through disadvantages of Artificial Potential Field (APF) approach like local minima issues, create an efficient path planning and develop the goodness of the mobile robot path planning [Ahmed et.al, 2015]. Various algorithms have been proposed for this purpose, Particle Swarm Optimization (PSO) is one of the most used algorithms.

WHEELED MOBILE ROBOT PARADIGM

In general, mobile robot is a type of electromechanical system [Al–Araji, 2014]. The paradigm as shown in Fig. 1 consists of a cart with two driving wheels mounted on the same axis and an omni-directional castor in the face of cart. The castor carries the mechanical body and saves the platform more stable. The radius of left and right wheel is r, the distance between the two wheels is L, while the center of wheeled mobile robot mass is c.

The position and orientation vector in the global coordinate [O, X, Y] of the mobile robot is located as equation (1):

$$q = (x , y , \theta)^T \tag{1}$$

Where the real position of the mobile robot is denoted as (x and y) while the orientation of the mobile robot is denoted as (θ). The coordinates (x, y, θ) depict the arrangement of the wheeled mobile robot.

Based on a non-holonomic constraints as in equation (2) [Al-Araji, 2014], the kinematic equations of the mobile robot model can be described in equations (3, 4, 5) after achievement the two conditions, the first one is a pure rolling wheels and the second is non-slipping wheels.

$$-\dot{x}(t)sin\theta(t) + \dot{y}(t)cos\theta(t) = 0 \tag{2}$$
$$\dot{x}(t) = VI(t)\cos(\theta(t)) \tag{3}$$
$$\dot{y}(t) = VI(t)\sin(\theta(t)) \tag{4}$$
$$\dot{\theta}(t) = Vw(t) \tag{5}$$

Where, VI is represented the linear velocity while Vw is represented the angular velocity.

The reference linear velocity for the optimal path is described in equation (6) , while the reference angular velocity is describe in equation (7) [Al-Araji, et.al, 2011]

$$Vr = \sqrt{(\dot{xr})^2 + (\dot{yr})^2} \tag{6}$$
$$wr = \frac{\ddot{yr}\dot{xr} - \ddot{xr}\dot{yr}}{(\dot{xr})^2 + (\dot{yr})^2} \tag{7}$$

Consequently, the right wheel velocity and left wheel velocity can be calculated as in Equation (8) [Al-Araji, et.al, 2011] based on equations (6 and 7).

$$\begin{bmatrix} VL(t) \\ VR(t) \end{bmatrix} = \begin{bmatrix} vr + \frac{L}{2}wr \\ vr - \frac{L}{2}wr \end{bmatrix} \tag{8}$$

PATH PLANNING PROBLEM

The robot path planning issue is very challenging in robotics. The major aim is to find a desired route between start and target points. Robot navigation issue has to be interested in two essential elements: accuracy and safety. That means transact with finding obstacle avoidance route and attached the desired path. [Abdulsahib , 2016].

OPTIMIZATION TECHNIQUES

Standard Particle Swarm Optimization (PSO) Algorithm

Particle Swarm Optimization is a meta-heuristic search technique. It means algorithm update the information at each iteration. Particle Swarm Optimization was developed in 1995 by James Kennedy and Russell Eberhart which is a Swarm Intelligence (SI) based stochastic optimization technique. Swarm intelligence is emerging research area which is similar to genetic algorithm. Swarm intelligence used to solve optimization and cooperative problems among intelligent particles [Abbas, et.al, 2016].

In the next iteration these particles are update their velocity according to equations (9, 10):

$$Vi^{x}(k+1) = WVi + c1r1[pbesti(k) - xi(k)] + c2r2[gbest(k) - xi(k)] \quad (9)$$

$$Vi^{y}(k+1) = WVi + c1r1[pbesti(k) - yi(k)] + c2r2[gbest(k) - yi(k)] \quad (10)$$

i: 1, 2, 3…… N_{pop}

k: the current iteration …… Maxit

Where N_{pop} is the size of the swarm , Maxit is the maximum no. of iterations ,r1 and r2 are the random functions between [0,1] ,W is the inertia weight , c1 is the personal learning coefficient , c2 is the global learning coefficient ,pbest is the best weight of each particle and gbest is the best particle among all the particles in the population.

In the next iteration these particles are then move to next position according to equations (11, 12):

$$Xi(k+1) = Xi(k) + Vi^{x}(k+1) \quad (11)$$

$$Yi(k+1) = Yi(k) + Vi^{y}(k+1) \quad (12)$$

PSO algorithm can be summarized in pseudo code as shown below:

Algorithm 1: Standard Particle Swarm Optimization algorithm
Step 1: initialize particles with random position and velocity Pbest and Gbest **Step 2:** initialize PSO parameters: Maxit= Max no. of iteration N_{pop} = swarm size i= the current particle k= the current iteration c1,c2=1.5 and W=1 **Step 3:** For each particle calculate the objective function **Step 4:** For each particle set Pbest =current objective function **Step 5 :** For all particles in the swarm set best objective value =Gbest **Step 6:**For each particle in the swarm Update velocity as stated by Eqs 9&10 Update position as stated by Eqs 11&12 **Step 7:** Repeat to step 3 until stopping criteria is satisfied

Chaotic Particle Swarm Optimization (CPSO)

Chaotic PSO is a stochastic search technique that differs from any of the present swarm intelligence approaches and evolutionary computation. Chaotic PSO can execute global searches at higher speeds than stochastic techniques that depend on probabilities [Assarzadeh, et.al, 2016].

The PSO Technique is a new evolution technology, has many power point, such as simple algorithm and quick convergence, but in the last stage of iterations of the algorithm when all particles approach the optimal solution, the convergence may become slow and the solution precision may not be absolutely satisfactory. The chaotic search algorithm was developed for nonlinear constrained optimization problems [Liu Yi, 2016]. PSO and chaotic sequence methods are integrated in order to arrange a chaotic searching behavior. The logistic equation is described as in equation (13) [Hussain, et.al, 2013]:

$$\beta\ k{+}1 = \mu\beta k\ (1-\beta k) \qquad 0 \le \beta\ 1 \le 1 \tag{13}$$

Where μ is the control parameter with a real value between [0, 4] [16]. The inertia weight perform in (9) and (10) is typically estimated employing as describe in equation (14):

$$W{=}W_{max} - [(W_{max} - W_{min})\ (k \backslash Maxit)] \tag{14}$$

Where $W_{max}$is the maximum value equal to 0.9 and $W_{min}$is the minimum value of equal to 0.3, the new inertia weight $W_{new}$is became as shown in equation (15):

$$w_{new} = w \times \beta k{+}1 \tag{15}$$

To develop the global searching ability of simple PSO, the new update velocity will be as in equations (16 & 17):

$$Vi^{x}(k+1) = WnewVi(k) + c1r1[pbesti - xi(k)] + c2r2[gbest - xi(k)] \tag{16}$$
$$Vi^{y}(k+1) = WnewVi(k) + c1r1[pbesti - yi(k)] + c2r2[gbest - yi(k)] \tag{17}$$

Chaotic PSO algorithm can be summarized in pseudo code as shown below:

Algorithm 2: Chaotic Particle Swarm Optimization algorithm
Step 1: initialize particles with random position and velocity Pbest and Gbest **Step 2:** initialize PSO parameters: Maxit= Max no. of iteration N_{pop} = swarm size n= Max no .of particles i= the current particle k= the current iteration c1,c2=1.5 ,β=3 , μ=4 , Wmin=0.3 and Wmax =0.9 **Step 3:** For each particle calculate the objective function **Step 4:** For each particle set Pbest =current objective function **Step 5 :** For all particles in the swarm set best fitness value =Gbest **Step 6:** For each iteration Calculate β according to Eq.7 Calculate W according to Eq .8 Calculate W_{new} according to Eq .9 **Step 7:** For particle in the swarm Update velocity as stated by Eqs 16&17 Update position as stated by Eqs 11&12 **Step 8:** Repeat to step 3 until stopping criteria is satisfied

WHEELED MOBILE ROBOT PATH PLANNING USING CHAOTIC PSO

The Particle Swarm Optimization technique can be applied to the wheeled mobile robot to find a desired route while navigating in the environment.

Algorithm steps:

1- Make the environment as be 2D square map. The size of the environment is 10×10 in (m × m). The left lowest place of the environment is the beginning point for the path while the right highest place of the environment is the end point for a path. The shape of an obstacle is circles and the size of an obstacle is variable.

2- The wheeled mobile robot is not a point, the dimension of the robot is added to the dimension of an obstacle to assuring the safety of robot while trying in the environment.

3- PSO technique use a swarm of particles (agents) whose locations act the possible solutions for the intended issue, with velocities are randomly initialize in the map .

4- The agents are evaluated using function to see how they are relative to the optimal route and the stability of the PSO algorithm. The shortest distance is the objective function which makes the mobile robot travel in the static environment with shortest time and distance as shown in equation (18) :

$$ML = \sum_{i=1}^{np-1} \sqrt{\left(X(i+1) - X(i)\right)^2 + \left(Y(i+1) - Y(i)\right)^2} \tag{18}$$

5- The particle fitness is match with its previous best fitness Pbest for every iteration to determine the next possible coordinate position for robot in the search environment. The next possible velocity and position of each robot are determine according to (16) and (17)

6- If the next position comes into the impact of obstacle then obstacle is avoided by violation as in equations (19, 20 & 21).

$$Violation = violation + mean(V) \quad (19)$$

$$V = \max(1.2 - D/R, 0) \quad (20)$$

$$D = \sqrt{\left(x - xobs(k)\right)^2 + \left(y - yobs(k)\right)^2} \quad (21)$$

Where D is Euclidian distance between obstacle and robot, R is the size of obstacles, xobs and yobs are obstacles coordination.

7- If obstacle is not present robot has to move to the next position.

8- Calculate Linear and angular velocities according to (6) and (7).

SIMULATION RESULTS

In all simulation fields , the swarm size N_{pop} =20, Number of Way Points M=3, Maximum number of iteration =100, personal factor c_1=2, social factor c_2=2, inertia weight damping ratio wdamp =0.98, distance between two wheels L =0.36m , radius of right and left wheel r=0.075m , sampling time Ts =0.1 s ,β=3, μ=4 . Simulation is carried out in MATLAB R2014 environment. The MATLAB codes are run on a computer system with 8G RAM and core i7 CPU.

Case Study 1: Path planning without obstacles

In this case study, there is no obstacles are located in the work space, its show the shortest path is (11.3137). The Fig.2 and Fig.3 shows the results of PSO algorithm.

Case Study 2: Path planning with eight obstacles

In case study 2, eight obstacles with variable size are located in the static environment. All obstacles positions are recorded in Table 1.

Case Study 2.1: Standard PSO

The optimal path with shortest distance using standard PSO is equal to (11.4709) with in iteration (47). The Fig. 4 and Fig.5 shows the converge results of Standard PSO algorithm. Finally, the reference linear velocity and the reference angular velocity of platform based on standard PSO for the optimal path are shown in Fig. 6 while the linear and angular velocities of right and left wheel are shown in Fig.7 and Fig. 8, respectively.

Case Study 2.2: Chaotic PSO

The best path with shortest distance using Chaotic PSO algorithm is equal to (11.468) in iteration (20) .The Fig. 9 and Fig. 10 shows the results of Chaotic PSO algorithm. Finally, the reference linear velocity and the reference angular velocity of platform based on standard PSO for the optimal path are shown in Fig. 11 while the linear and angular velocities of right and left wheel are shown in Fig. 12 and Fig. 13, respectively.

In addition, table 2 summarized a comparison results between two optimization algorithms. It is clearly to say that Chaotic PSO get best path length than standard version of PSO with less number of iterations.

CONCLUSION

Path planning is an important problem in mobile robot navigation. In this work a comparative study between two optimization techniques is presented to find the best route for wheeled mobile robot on a static environment. First PSO had been applied to find the best path for mobile robot, then chaotic PSO applied to enhance the results of path planning algorithm. The simulation results have shown that the path found by Chaotic PSO is shorter than the path of PSO with less number of iteration.

Table 1: Definition of obstacles.

Obstacle	Radius (m)	Center (xob,yob)
1	0.32	(1,8)
2	0.62	(1.5,4.5)
3	0.32	(3,7)
4	0.32	(4,3)
5	0.82	(9,4)
6	0.32	(8,8)
7	0.52	(6,6)
8	0.62	(9,1)

Table 2: The results of two algorithms.

Performance	The results of the Standard PSO	The results of the Chaotic PSO
The best length path in (m)	11.4709	11.468
The iteration of Best Path	47	20
Execution Time (sec)	28.4887	25.2379

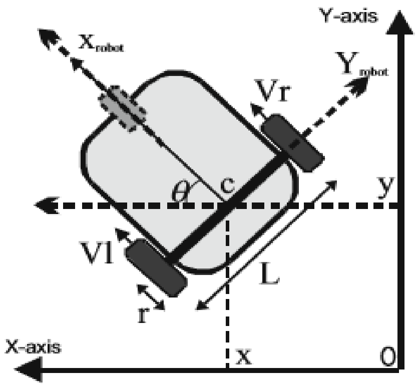

Fig. 1: Mobile Robot Model [1].

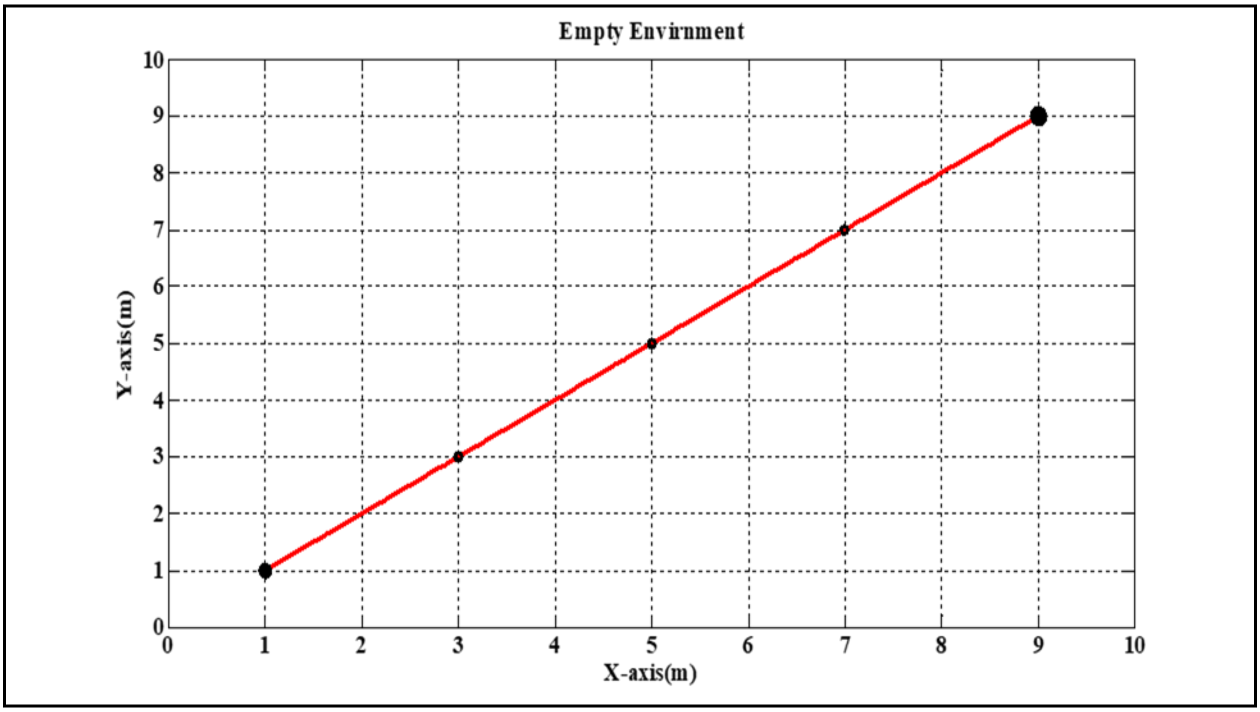

Fig. 2: Path Planning with Empty Map.

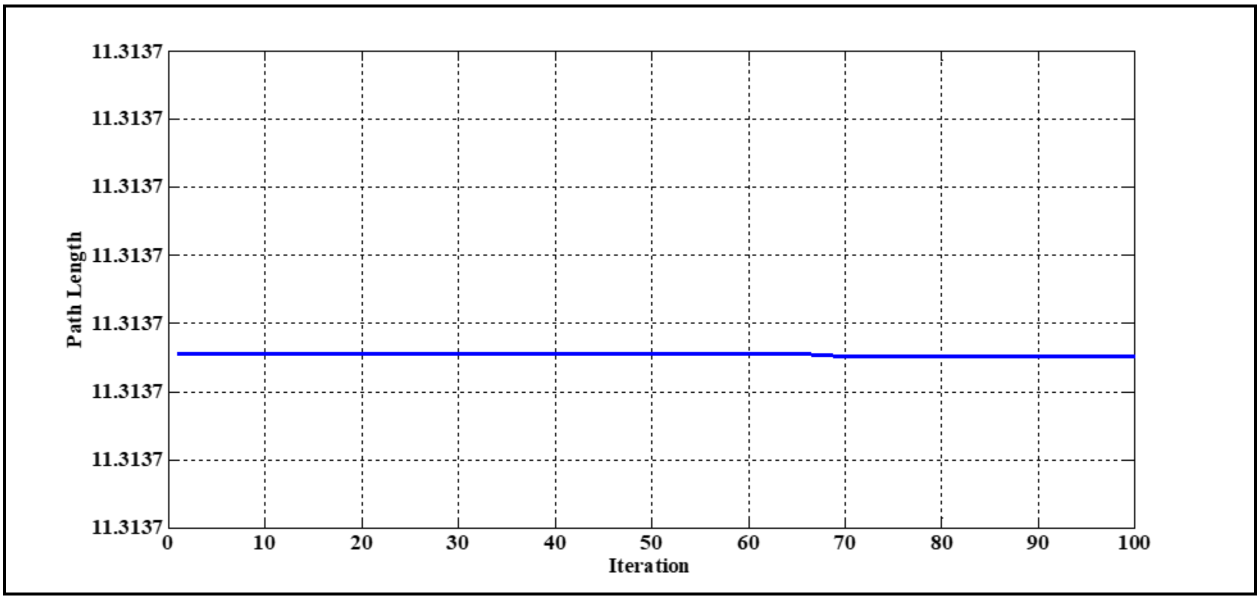

Fig. 3: The convergence Curve for empty map.

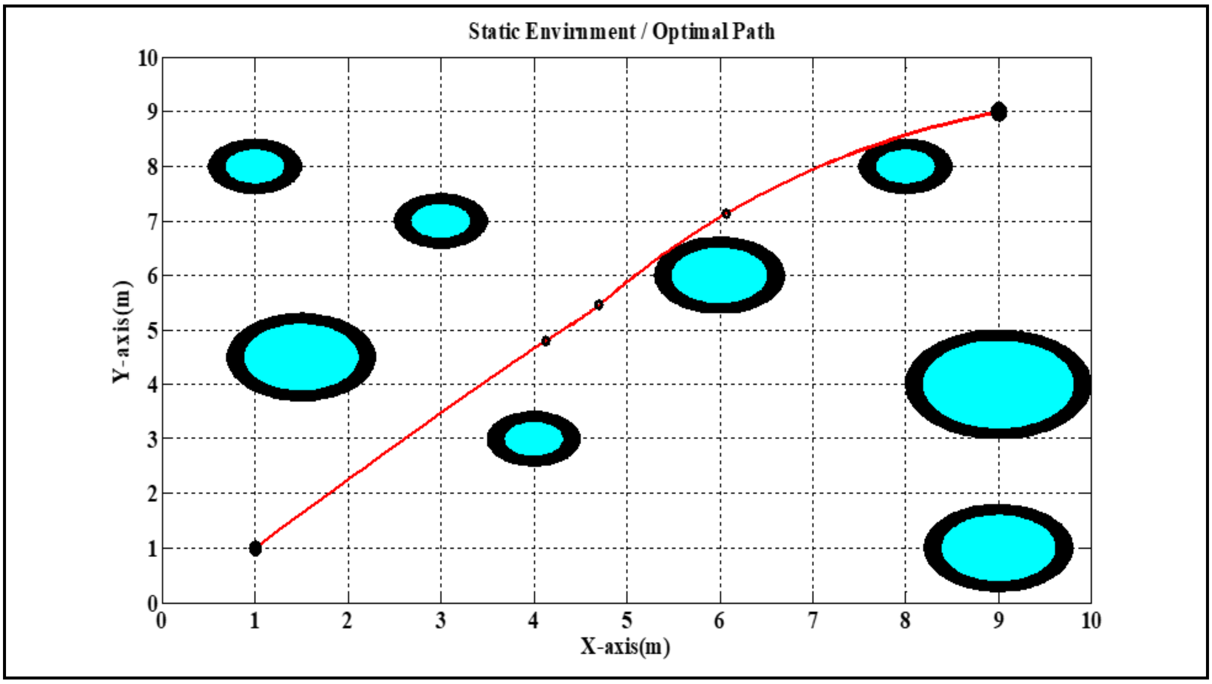

Fig. 4: Best path found by Standard PSO.

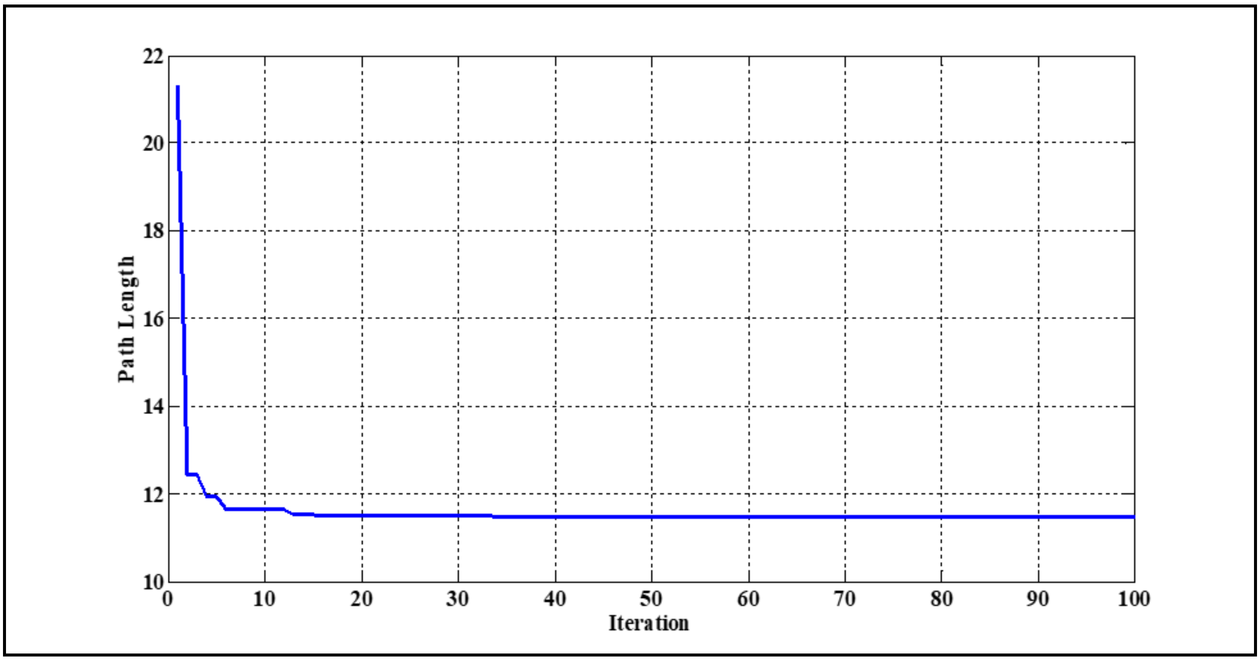

Fig. 5: The convergence Curve for Standard PSO algorithm.

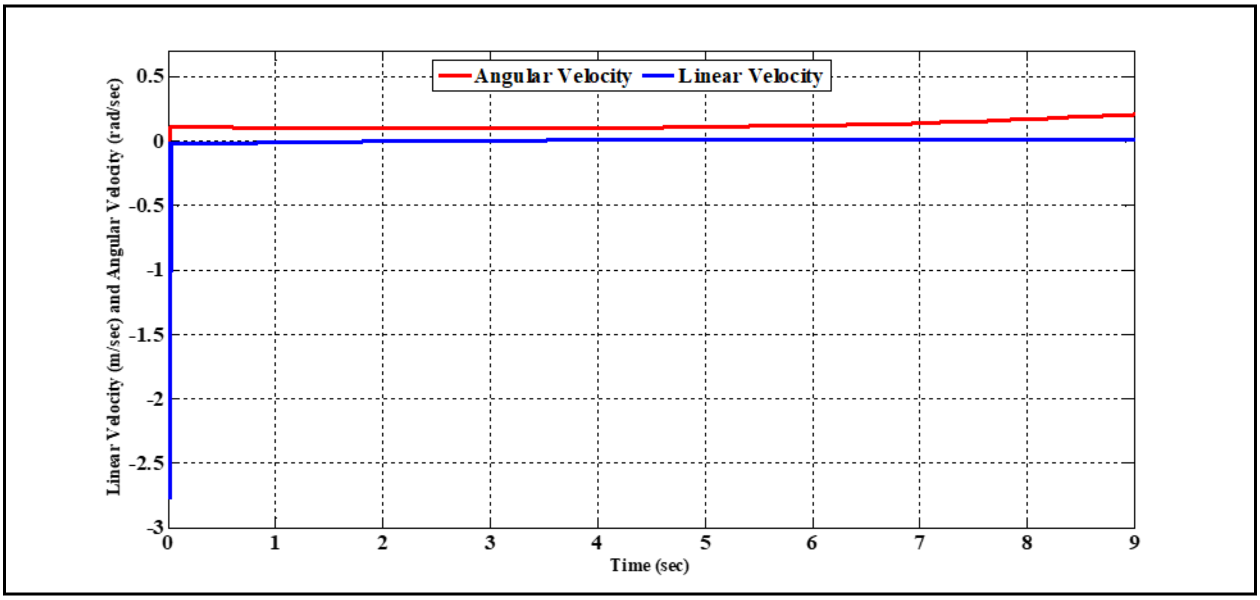

Fig. 6: Linear and Angular Velocity of platform based on PSO.

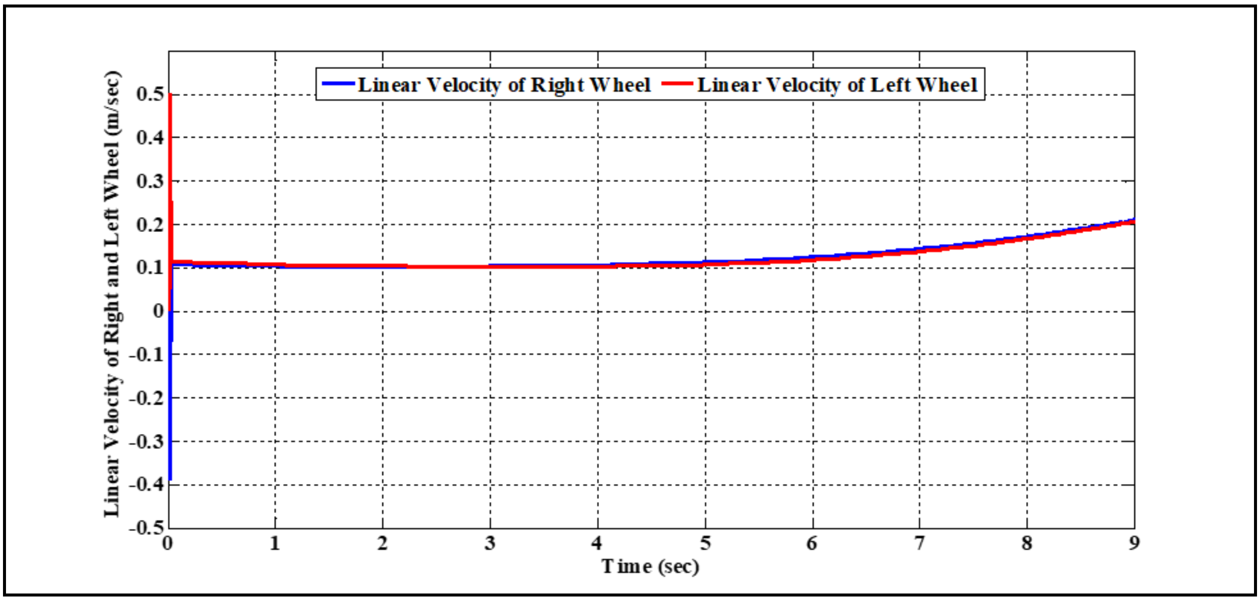

Fig. 7: Linear Velocity of right and left wheel based on PSO.

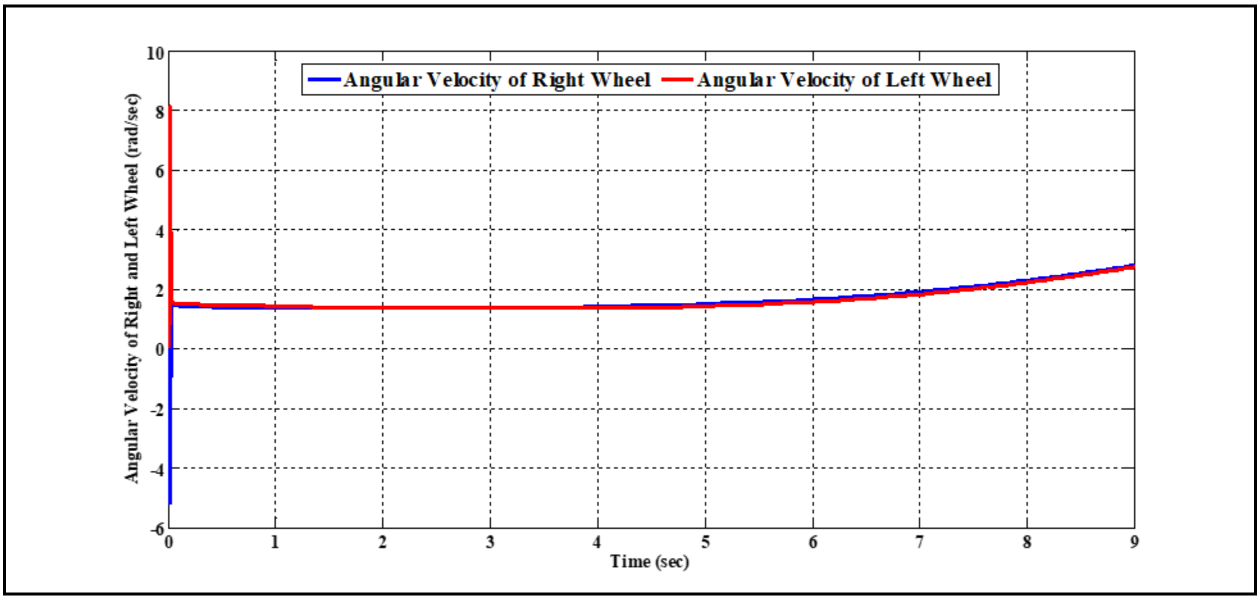

Fig. 8: Angular Velocity of right and left Wheel based on PSO.

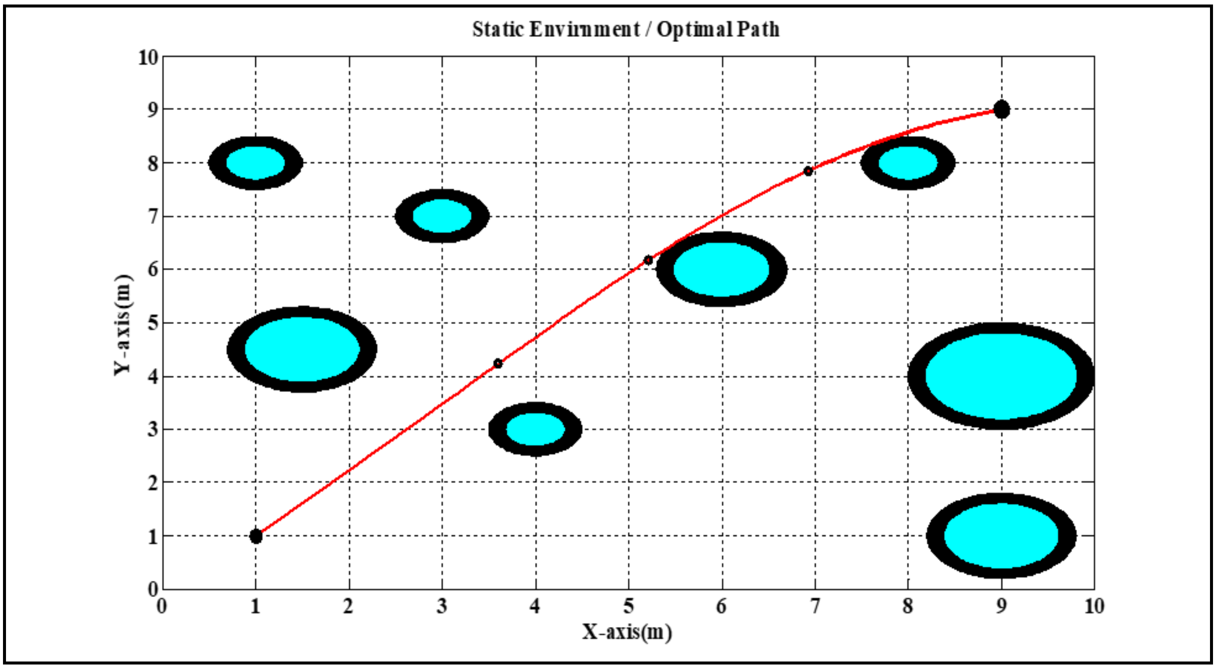

Fig. 9: Best Path found by Chaotic PSO.

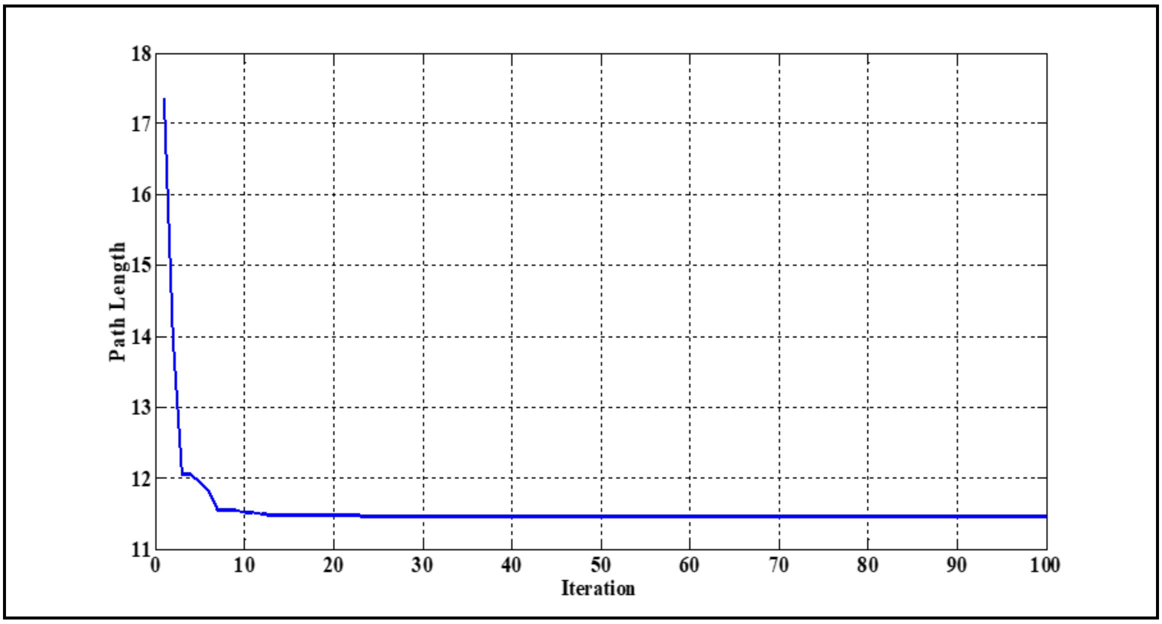

Fig. 10: The Convergence Curve for Chaotic PSO.

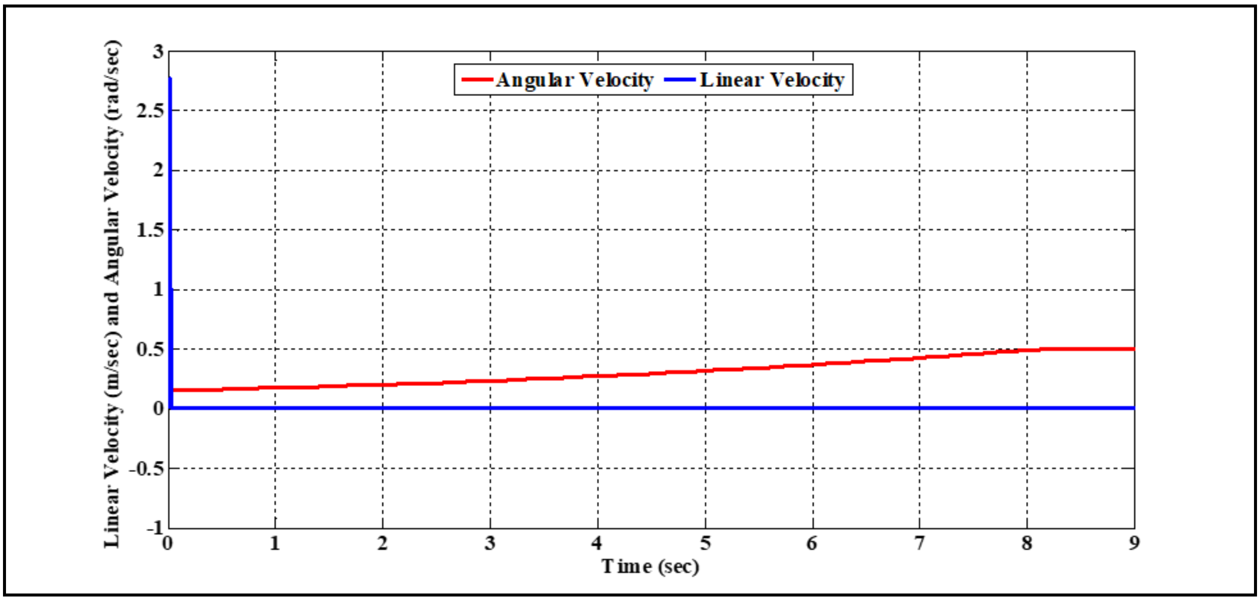

Fig. 11: Linear Velocity and angular Velocity of platform based CPSO.

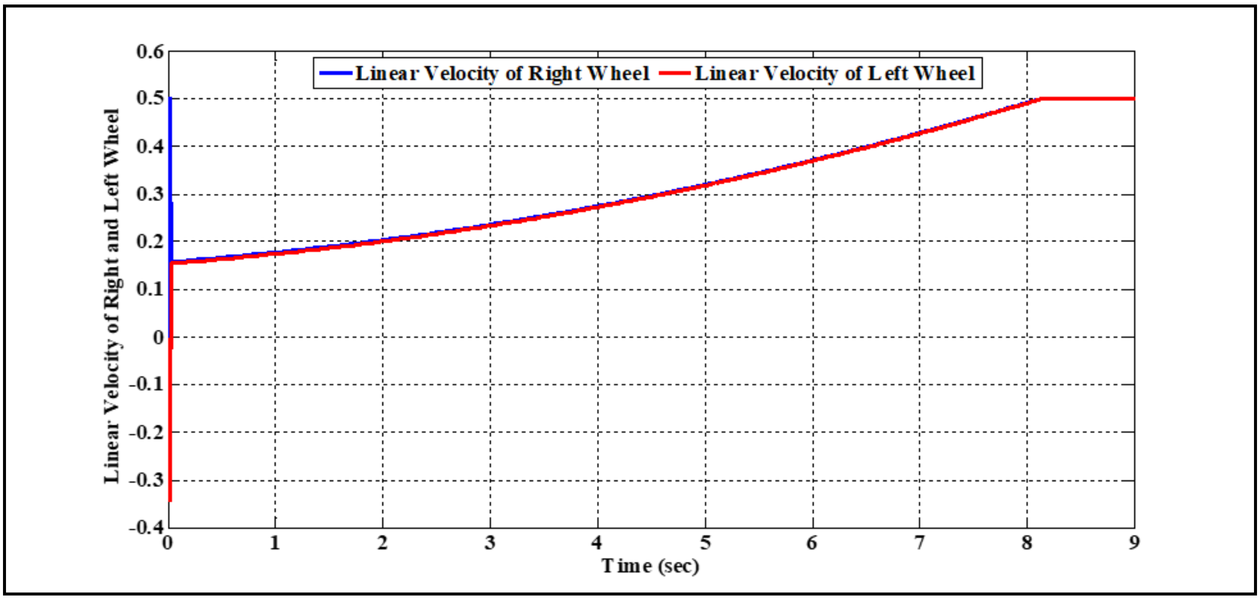

Fig. 12: Linear Velocity of right wheel and left wheel based on CPSO.

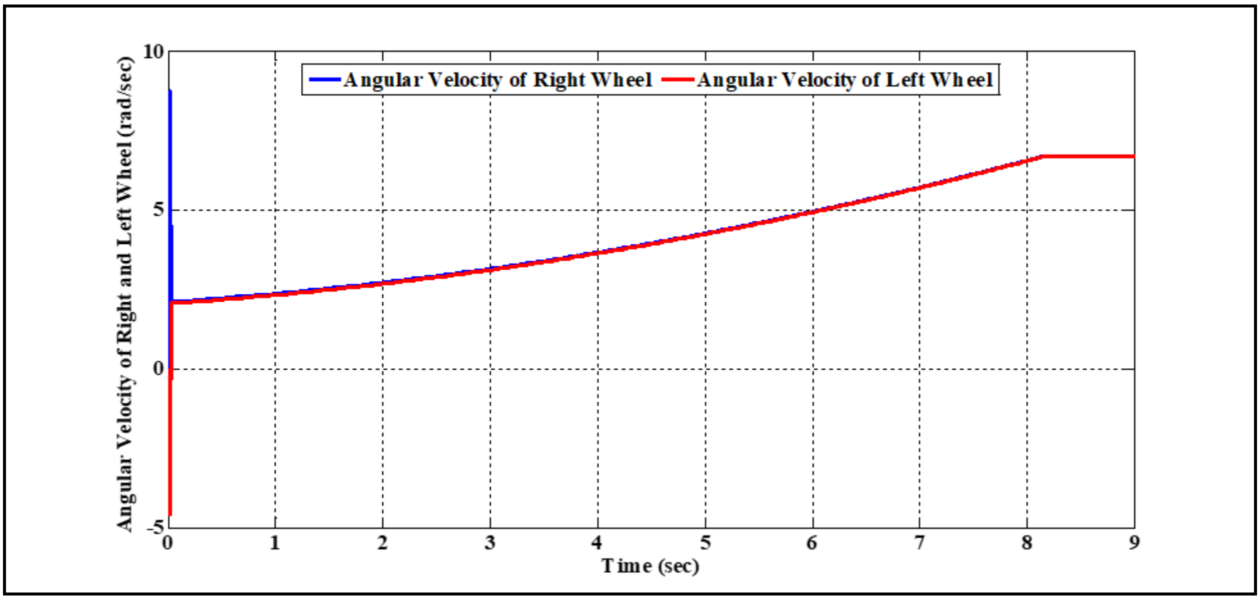

Fig. 13: Angular Velocity of right wheel and left wheel based on CPSO.

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