Al-Khwarizmi Engineering Journal,Vol. 13, No. 3, P.P. 64- 73 (2017)

Al-Khwarizmi Engineering Journal

A Cognitive Hybrid Tuning Control Algorithm Design for Nonlinear Path-Tracking Controller for Wheeled Mobile Robot

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(Received 13 December 2016; accepted 7 March 2017)

https://doi.org/10.22153/kej.2017.03.004

Abstract

This research presents a on-line cognitive tuning control algorithm for the nonlinear controller of path-tracking for dynamic wheeled mobile robot to stabilize and follow a continuous reference path with minimum tracking pose error. The goal of the proposed structure of a hybrid (Bees-PSO) algorithm is to find and tune the values of the control gains of the nonlinear (neural and back-stepping method) controllers as a simple on-line with fast tuning techniques in order to obtain the best torques actions of the wheels for the cart mobile robot from the proposed two controllers. Simulation results (Matlab Package 2012a) show that the nonlinear neural controller with hybrid Bees-PSO cognitive algorithm is more accurate in terms of fast on-line finding and tuning parameters of the controller lead to obtaining smoothness with small spikes control action as well as minimizing tracking pose error of the wheeled mobile robot than the performance of nonlinear back-stepping technique.

Keywords: *Bees Algorithm, Nonlinear Controller, Matlab Package, Particle Swarm Optimization, Wheeled Mobile Robots.*

1. Introduction

In general, a wheeled mobile robot system considers a multi-input multi-output nonlinear dynamic and time variant system and the one of fundamental problems in the control engineering is the motion control design to track the desired path [1] because the mobile robot has many applications in various directions life such as: science; education; industry; entertainment; security and military therefore the mobile robot is still active region of research [2].

In the recent years, different types of control algorithms and controllers that they are based on mathematical model of the wheeled mobile robot and they are proposed to solve the motion control of the robot's wheels in order to follow the desired trajectory with high performance of the controllers in terms of generating optimal action that lead to minimizing tracking pose error during tracking reference path, such as nonlinear neural PID controllers [3 and 4], fuzzy logic and PID controllers [5 and 6], neural networks controllers [7 and 8], back-stepping controllers [9 and 10], adaptive sliding mode controllers [11 and 12] and neural predictive controllers [13 and 14].

The motivation for this research is taken from [2, 3, 4 and 10] which are focusing on the problems of the mobile robot in terms of tracking and stabilizing the mobile robot on the desired path as well as how can generate best torque control action without saturation state and no spike action?

The main core of the contribution of this research is described as follows:

- Using a different types of controllers with high computational accuracy that have been derived of the control laws in order to generate best torque action and lead to minimizing tracking pose error of the wheeled mobile robot.
- Cognitive hybrid Bees-PSO optimization algorithm proposed to show the ability in the fast search in local (PSO) and global (Bees)

regions in order to find and tune on-line the best parameters of the two types of controllers.

- Adding a dynamic disturbance to investigate the robustness performance of the proposed controllers.
- Changing the initial pose state to verify the adaptation performance of the proposed controllers.
- Tracking a variable radius continuous trajectory to validate the capability of the proposed controllers.

The organization of this paper can be described as follows: in Section two, is a description of the dynamic wheeled mobile robot model. Section three is deriving the different types of the proposed nonlinear controllers. In section four, the proposed of a cognitive hybrid Bees-PSO optimization algorithms is explained. Section five is presented the performance of the proposed controllers through simulation results. In section five, the conclusions are drawn.

2. Model of a Dynamic Wheeled Mobile Robot

Fig.1 shows the schematic diagram of the cart wheeled mobile robot that it consists of a two DC motors which is driving the two wheels with one an omni-directional castor wheel that will stabilize the platform of the mobile robot [12 and 13]. The motion and orientation of the mobile robot depends on a two independent actuators (DC motors) for left and right wheels. r is the radius of the same of the two wheels and the distance between these wheels is L and c is the center of gravity of the mobile robot.

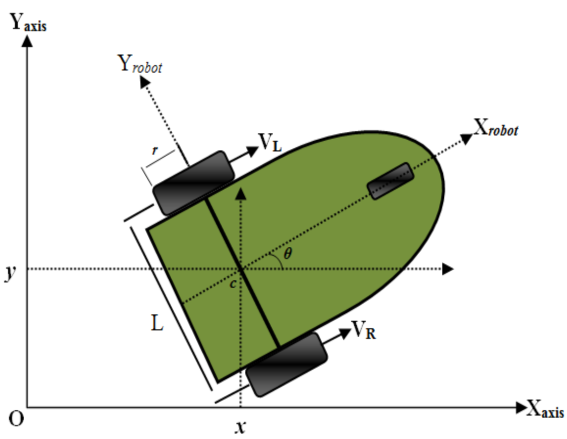

Fig. 1. Mobile robot Platform model.

In general, the global coordinate frame is defined as $[O, X, Y]$ while the pose vector of the mobile robot in the surface is defined as:

$$q = (x, y, \theta)^T \quad \text{... (1)}$$

The position coordinates (x,y) are at point c while θ is orientation angle that is measured with respect to global frame in the X-axis therefore the configuration of mobile robot can be described by these three generalized coordinates.

To investigate the motion and orientation of the wheeled mobile robot, two conditions should be achieved; the first is pure-rolling and the second is without-slipping in order to make the mobile robot's lateral velocity is equal to zero as equation (2) [3 and 4].

$$-\dot{x}(t)\sin\theta(t) + \dot{y}(t)\cos\theta(t) = 0 \quad \text{...(2)}$$

Then, the equations of the kinematics wheeled mobile robot in the world frame can be represented as follows [7 and 10]:

$$\dot{x}(t) = \frac{r(wr(t) + wl(t)}{2})\cos\theta(t) \quad \text{...(3)}$$

$$\dot{y}(t) = \frac{r(wr(t) - wl(t))}{2}\sin\theta(t) \quad \text{...(4)}$$

$$\dot{\theta}(t) = \frac{r(wr(t) - wl(t))}{L} \quad \text{...(5)}$$

where *wr(t)* and *wl(t)* are the right and left angular velocities respectively.

Based on Euler Lagrange formulation [9 and13], the dynamic model of the mobile robot can be described as follows:

$$\begin{bmatrix} M & 0 & 0 \\ 0 & M & 0 \\ 0 & 0 & I \end{bmatrix}\begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{\theta} \end{bmatrix} + \tau d = \frac{1}{r}\begin{bmatrix} \cos\theta & \cos\theta \\ \sin\theta & \sin\theta \\ \frac{L}{2} & \frac{-L}{2} \end{bmatrix}\begin{bmatrix} \tau_L \\ \tau_R \end{bmatrix} + \begin{bmatrix} -\sin\theta \\ \cos\theta \\ 0 \end{bmatrix}\lambda \quad \text{..(6)}$$

where

τ_L is the torque of the left wheel.

τ_R is the torque of the right wheel.

M is the mobile robot's mass.

I is the mobile robot's inertia.

λ is the constraint forces.

τ_d is bounded dynamic disturbances.

The pose equations of the mobile robot in the simulation can be described as follows:

$$F(k) = \frac{\tau_L(k)+\tau_R(k)}{r} \quad \text{...(7)}$$

$$\tau_a(k) = \frac{0.5L[\tau_L(k)-\tau_R(k)]}{r} \quad \text{...(8)}$$

$$Acc_{Lin}(k) = \frac{F(k)}{M} \quad \text{...(9)}$$

$$Acc_{ang}(k) = \frac{\tau_a(k)}{I} \quad \text{...(10)}$$

$$V_{Lin}(k) = Acc_{Lin}(k) \times \Delta t \quad \text{...(11)}$$

$$V_{ang}(k) = Acc_{ang}(k) \times \Delta t \quad \text{...(12)}$$

$$wr(k) = \frac{0.5[2V_{Lin}(k)+V_{ang}(k)L]}{r} \quad \text{...(13)}$$

$$wl(k) = \frac{0.5[2V_{Lin}(k)-V_{ang}(k)L]}{r} \quad ...(14)$$

$$x(k) = 0.5r[wr(k) + wl(k)]\cos\theta(k)\Delta t + x(k-1) \quad ...(15)$$

$$y(k) = 0.5r[wr(k) + wl(k)]\sin\theta(k)\Delta t + y(k-1) \quad ...(16)$$

$$\theta(k) = \frac{r}{L}[wr(k) - wl(k)]\Delta t + \theta(k-1) \quad ...(17)$$

where F is total linear force; τ_a is total angular torque; Acc_{Lin} is linear acceleration; Acc_{ang} is angular acceleration; V_{Lin} is linear velocity; V_{ang} is angular velocity; wl is angular velocity of the left wheel; wr is angular velocity of the right wheel; $x(k), y(k), \theta(k)$ are the pose of the mobile robot at each step k^{th} of the movement and Δt is the sampling time.

3. Nonlinear Controller Methodology

In general, a feedback control signal based on different types of the nonlinear controllers are very important in the structure of the proposed controller in terms of stabilizing and minimizing the tracking pose error of the wheeled mobile robot during the mobile robot's pose is drifted from the reference path.

Block diagram of the proposed structure of the nonlinear trajectory tracking controllers for wheeled mobile robot can be shown in Fig. 2.

The first structure of the nonlinear controller equation is neural network that it performed as a nonlinear PID controller [3 and 4]. The nonlinear neural control structure has strong of adaptation performance, high dynamic characteristic and good robustness performance because the proposed structure is built on a traditional PID controller and employed the theory of the neural network technique. The structure of the proposed nonlinear neural controller can be shown in Fig. 3. The proposed control law of the nonlinear neural controller for the right and left torques as follows:

$$\tau_R(k) = B_1\tau_R(k-1) + B_{11}o_x + B_{12}o_y \quad (18)$$

$$\tau_L(k) = B_{15}\tau_L(k-1) + B_{13}o_y + B_{14}o_\theta \quad ...(19)$$

The outputs o_x, o_y and o_θ of the neural networks.

Sigmoid function is used as nonlinear relationship as equation (20) [3 and 4]:

$$o_\gamma = \frac{2}{1+e^{-net_\gamma}} - 1 \quad ...(20)$$

Where $\gamma = x, y, \theta$.

net_γ is calculated from these equations:

$$net_x(k) = B_2[e_x(k)] + B_3[e_x(k) + e_x(k-1)] + B_4[e_x(k) - e_x(k-1)] \quad ...(21)$$

$$net_y(k) = B_5[e_y(k)] + B_6[e_y(k) + e_y(k-1)] + B_7[e_y(k) - e_y(k-1)] \quad ...(22)$$

$$net_\theta(k) = B_8[e_\theta(k)] + B_9[e_\theta(k) + e_\theta(k-1)] + B_{10}[e_\theta(k) - e_\theta(k-1)] \quad ...(23)$$

where

$e_\gamma(k)$ is the input error signal.

The control parameters B1, B2, … and B15 are on-line updated by using cognitive hybrid Bees-PSO optimization algorithm.

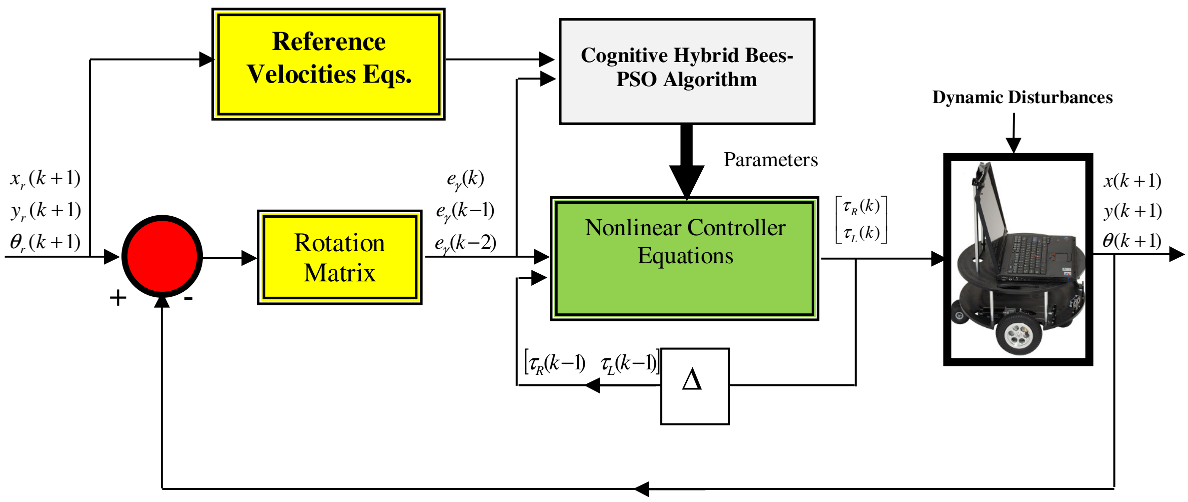

Fig. 2. The proposed structure of nonlinear trajectory tracking controllers for mobile robot.

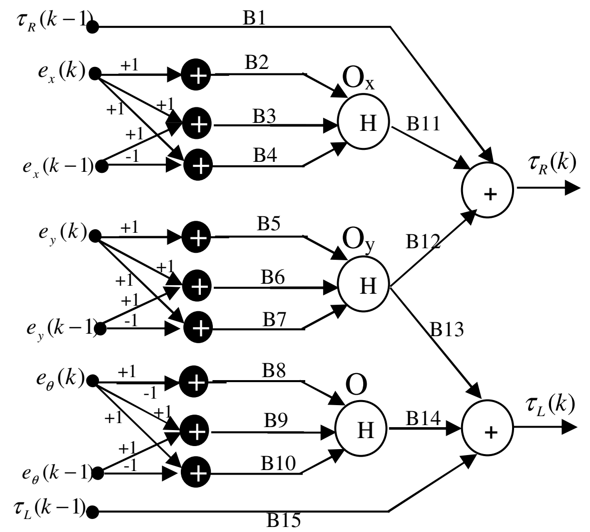

Fig. 3. The structure of nonlinear neural controller [3 and 4].

The second structure of the nonlinear controller equation is back-stepping technique based on Lyapounov method [10]. The nonlinear back-steeping controller method structure can be shown in Fig. 4.

Based on back-stepping technique in [9 and 10], the nonlinear angular velocity control law can be described by Eq. (24) and applying the proposed hybrid Bees-PSO tuning algorithm for finding and tuning the best value of the parameters (B1, B2 and B3) then solving equations (7 to 14) to find the right and left torques control action for wheeled mobile robot.

$$\begin{bmatrix} w_R \\ w_L \end{bmatrix} = \begin{bmatrix} \dfrac{(v_r \cos e_\theta + B_1 e_x + \frac{L}{2}(w_r + B_2 v_r e_y + B_3 v_r \sin e_\theta))}{r} \\ \dfrac{(v_r \cos e_\theta + B_1 e_x - \frac{L}{2}(w_r + B_2 v_r e_y + B_3 v_r \sin e_\theta))}{r} \end{bmatrix} \quad (24)$$

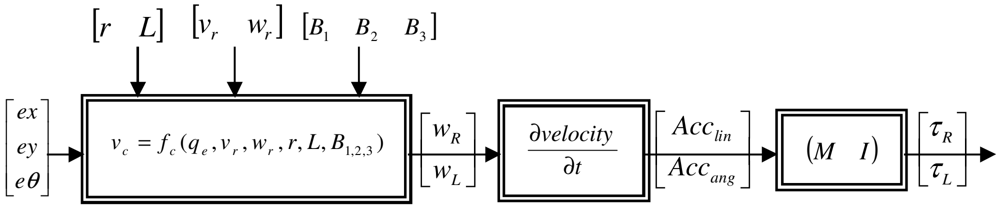

Fig. 4. The nonlinear back stepping controller structure [10].

4. Cognitive Hybrid Bees-PSO Algorithm

The purpose of the on-line cognitive hybrid Bees-PSO algorithm is to find and tune the optimal gains control for the proposed controller to generate the best and smoothness torque signal that will lead to minimizing the tracking pose error of the wheeled mobile robot during dynamic disturbance has been added.

In general, Bees algorithm mimics the food foraging behavior of swarms of honey bees and this algorithm carries out by using local (neighborhood) search that has two types of Bees (Selected and Recruit Bees) and global (random) search that has also two types of Bess (Scout and Fittest Bees) [15 and 16] while the particle swarm optimization (PSO) is considered one of the algorithms types that has a capability to search for the optimal solution by simulating the movement and flocking of birds. In PSO algorithm, the particles that have a position and velocity are a population of individual in order to move around the search space to find best or optimal solution through evaluation each particle by using a fitness function [3 and 4].

4.1. Hybrid Bee-PSO (HBPSO) Algorithm

In this work, the proposed on-line optimization algorithm is a hybrid tuning control algorithm which consists of Bees algorithm [15 and 16] and PSO algorithm [3 and 4].

The main advantages for this proposed optimization algorithm are to solve the problem of local search of the Bees algorithm using PSO algorithm which has the high ability for local search through generating population (Recruit Bees) as particles and this will speed up the process of optimization while the problem of the global search in the PSO algorithm is solved by using Bees algorithm which has the capability of combining the (Fittest Bees) and a new population of (Scout Bees) generating in the global search.

The proposed on-line HBPSO algorithm is applied as a powerful optimization algorithm to find and tune the optimal stable parameters of the nonlinear neural controller in order to enhance the performance characteristics of the system by reducing the processing time as well as improve the response accuracy through minimizing the tracking error for mobile robot.

The proposed HBPSO algorithm's steps can be described as follows:

1. Scout Bees (n) are generated in the global (random) search as the initial population with randomly fifteen values of the controller's parameters in the nonlinear neural controller while only three control parameters in the nonlinear back-stepping controller.
2. Calculated the fitness of the (n) Scout Bees by using the fitness equation (25) [3] based cost function.

$$fitness = \frac{1}{\mu + Cost\ Function} \quad ...(25)$$

Where:

$\mu > 0$ to avoid division by zero.

The proposed cost function is a mean square error as equation (26).

$$MSE = \frac{1}{N}\sum_{i=1}^{N}[(x_{ref} - x)^2 + (y_{ref} - y)^2 (\theta_{ref} - \theta)^2 + (Vlin_{ref} - Vlin)^2 + (W_{ref} - W)^2] \quad ...(26)$$

N: is the number of iteration.

3. In the local search, chosen the number of particles depends on the number of the highest fitness for the Scout Bees (population) as (m) Selected Bees.
4. The size of (patch size) of the local search is determined by applying the proposed equations (27).

$$\Delta\bar{\beta} = 0.025 \times \bar{\beta}_{old} \times random(0,1) \quad ...(27)$$

$$\bar{\beta}_{new} = \bar{\beta}_{old} + \Delta\bar{\beta} \quad ...(28)$$

Where

$\bar{\beta}$: is the vector of the fifteen parameters of the proposed controller.

5. Particles are generated by using equations (28) to search and find the best controller's parameters.
6. Evaluated the proposed cost function of each particle using the mean square error equation (26).
7. Set to pbest for each particle in the current searching point. When the search is finding the best value of pbest then sets the pbest to gbest and store the number of the particle with the best value.
8. The pbest value is replaced by the current value if the value is better than the current pbest of the particle and if the best value of pbest is better than the current gbest, gbest is replaced by the best value and the particle number with the best value is stored.
9. Each particle is update by using Eqs. (29 and 30).

$$\Delta\bar{B}_m^{(k+1)} = \Omega\Delta\bar{B}_m^{(k)} + c_1 r_1 (pbest_m^{(k)} - \bar{B}_m^{(k)}) + c_2 r_2 (gbest^{(k)} - \bar{B}_m^{(k)}) \quad ...(29)$$

$$\bar{B}_m^{(k+1)} = \bar{B}_m^{(k)} + \Delta\bar{B}_m^{(k+1)} \quad ...(30)$$

where

$m = 1,2,3,.....pop$; $\bar{B}_m^{(k)}$ is the particle's weight m at k^{th} iteration; Ω : is the inertia weight factor; c_1 and c_2 are the positive values ; r_1 and r_2 are random numbers between 0 and 1; $pbest_m$ is best previous weight of m^{th} ;Particle and $gbest$ is best particle among all the particle in the population.

10. Return to step six if the current iteration number did not reach to the predefined maximum iteration number otherwise pick out the highest fitness for the particles as Fittest Bees (m).
11. Return to global search by assign the (n-m) remaining Bees to random search and generating a new population of Scout Bees.

In general, the steps of the on-line cognitive hybrid Bees-PSO optimization algorithm for finding and tuning control parameters are repeated at 0.1 second (sampling time) for each k^{th} sample based on Shannon theorem.

5. Simulation Results

MATLAB package used to verify the proposed nonlinear controllers of the trajectory tracking for the dynamic model of the wheeled mobile robot. The Eddie mobile robot platform specifications are picked from [17]: M=12kg is the mobile robot's mass; I=1.536kg.m^2 is the mobile robot's inertia; r=0.075m is the radius of wheel and L=0.39m is the distance between wheels.

The MATLAB simulation is carried out on-line cognitive tuning control algorithm with proposed controllers as shown in Figure (2) to track a reference pose with continuous variable radius path and 0.1 sec is sampling time. In this paper, two types of the nonlinear controllers are used (neural network and back-stepping technique) with hybrid Bees-PSO tuning control parameters to show which of them is batter in term of generating optimal and smoothness torque control action and minimizing the tracking error with minimum number of iteration. The parameters of the optimization hybrid Bees-PSO algorithm that will define as follows:

The Scout Bees (n) is equal to 10 at the global search; the Selected Bees is equal to 5; the particle is equal to 40 in the local search; the Fittest Bees is equal to 5; the iteration number (*N*) in the global search is equal to 3and the iteration number (*P*) in the local search is equal to 3.

Case Study

The reference pose trajectory for wheeled mobile robot can be described in below equations (31, 32 and 33):

$$x_r(t) = \sin(\frac{2\pi t}{20}) \quad \ldots(31)$$

$$y_r(t) = \sin(\frac{2\pi t}{40}) \quad \ldots(32)$$

$$\theta_r(t) = 2\tan^{-1}(\frac{\Delta y_r(t)}{\sqrt{(\Delta x_r(t))^2 - (\Delta y_r(t))^2} + \Delta x_r(t)}) \quad \ldots(33)$$

The mobile robot has initial pose as $q(0) = [-0.1, 0, \pi/4]$. After applying the structure of the cognitive hybrid Bees-PSO tuning control algorithm with two different types of the nonlinear controllers and adding small values of the dynamic disturbances as the term that taken from [14] $\overline{\tau d} = [0.01\sin(2t) \quad 0.01\sin(2t)]^T$ to show the controller ability of robustness through the on-line adaptation the parameters of these controllers. The trajectory tracking for mobile robot model can be shown in Fig. 5 which it is clearly, the excellent tracking performance depends on MSE of the mobile robot pose when was applying the nonlinear neural controller than nonlinear back-stepping controller because the cognitive hybrid Bees-PSO tuning control algorithm was found and tuned fifteen parameters of the nonlinear neural controller that covered the nonlinear operation regions while in the nonlinear back-stepping controller has three parameters only and could not cover these regions especially when adding a bounded dynamic disturbances. This proposed control algorithm has a capability of perfect search in two search space (local and global) with minimum number of iteration in both search space.

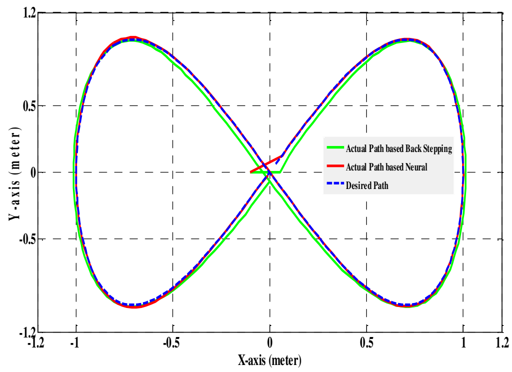

Fig. 5. The desired and actual trajectory for mobile robot.

In Fig. 6 demonstrates the orientation tracking performance of the mobile robot with two types of controllers.

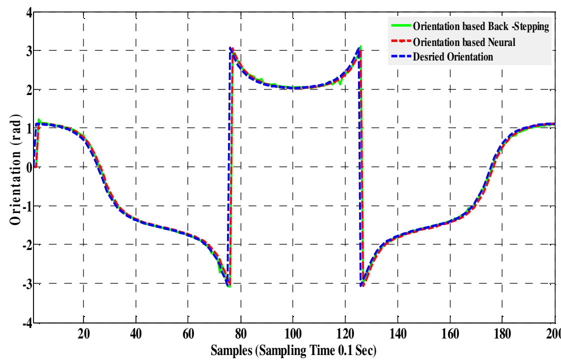

Fig. 6. The desired and actual orientation for mobile robot.

In this on-line tuning control algorithm, the proposed Mean Square Error (MSE) clearly improved the performance of these controllers by showing the pose error convergence for the mobile robot motion at 200 steps, as shown in Figs. 7 and 8.

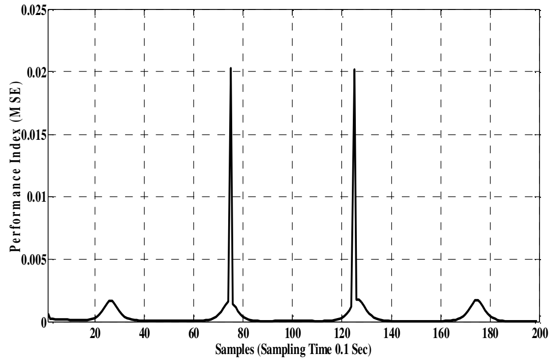

Fig. 7. On-line performance index for nonlinear neural controller.

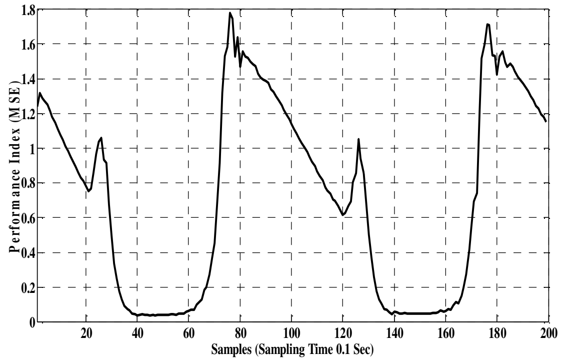

Fig. 8. On-line performance index for nonlinear back-stepping controller.

Fig. 9 shows the effectiveness of the nonlinear neural controller response through generating best torque control action without saturation control action state to track the desired path in minimum time while the torque control action for the nonlinear back-stepping controller can be shown in Fig. 10 which has non smoothens and not high spikes and reach to the maximum saturation torque action value in data sheet of motor [17] is 3 N.m only at starting and for very short time.

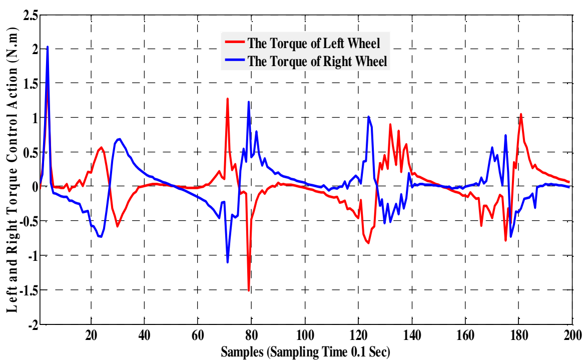

Fig. 9. Torque control action for nonlinear neural controller.

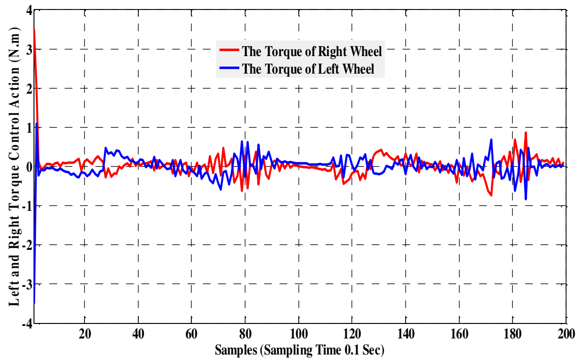

Fig. 10. Torque control action for nonlinear back-stepping controller.

The response of angular velocity of the left and right wheels of the platform Eddie wheeled mobile robot can be shown in Fig. 11 have smoothness response which are generated from nonlinear neural controller while the angular velocities of the left and right as shown in Fig. 12 have small spikes response that are generated from the nonlinear back-stepping controller.

It is clear, that the response between (60 to 80) samples and between (120 to 140) samples of the torque and angular velocity as shown in Figs. 9 and 11 respectively are non-smooth and have spikes because in this region the orientation in Fig. 6 is changing between -180° to 180° that needs to add 2pi for correcting the orientation and this big change will lead to small spikes and non-smooth response in this region.

Figs. 13-a,b,c show the robustness and adaptation performance of the proposed controller in terms of keeping on minimum tracking pose error for the wheeled mobile robot and stabilizing the pose of the mobile robot when the mobile robot tries to drift from the desired path because the effect of the bounded dynamic disturbances to the system.

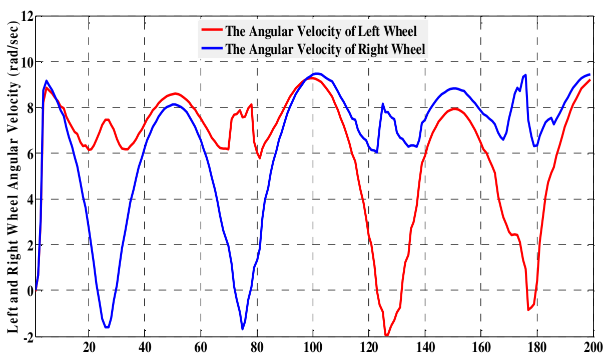

Fig. 11. Angular Velocities of the left and right wheels for nonlinear neural controller.

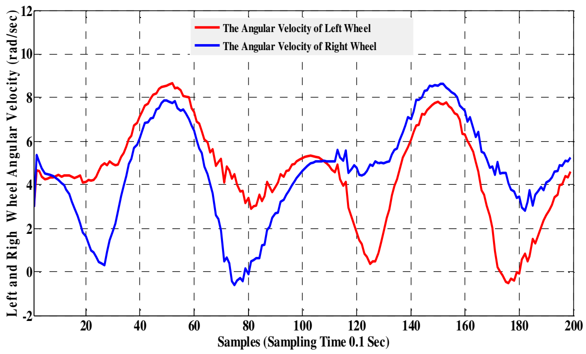

Fig. 12. Angular Velocities of the left and right wheels for nonlinear back-stepping controller.

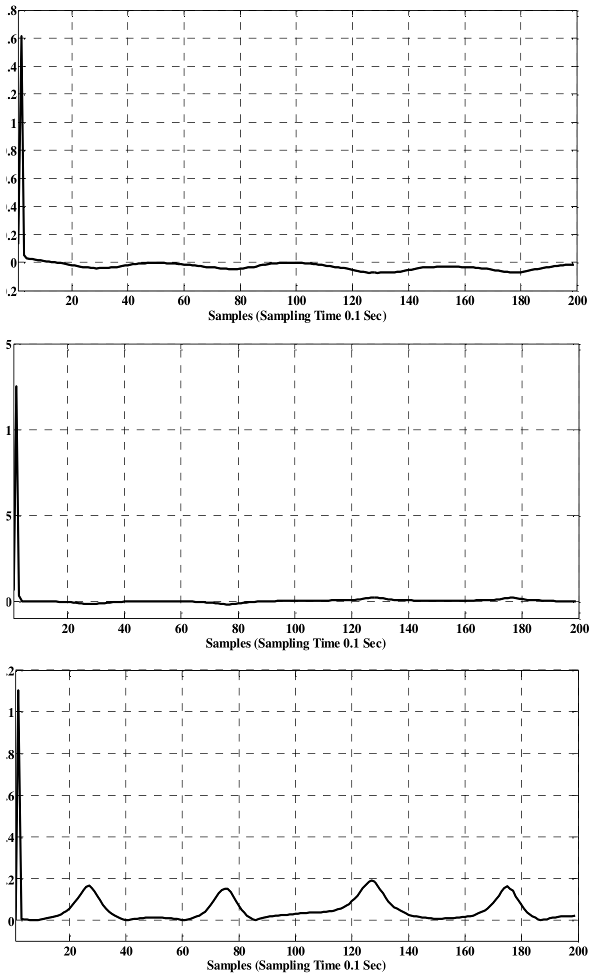

Fig. 13. Pose error of the mobile robot: a) error in X-axis; b) error in Y-axis; c) orientation error.

6. Conclusions

The simulation results on the on-line cognitive hybrid Bees-PSO tuning algorithm of different types of nonlinear controllers are presented in this paper for the dynamic wheeled mobile robot model which shows preciously and that the proposed hybrid Bees-PSO tuning control algorithm was better than the results in [3 and 4] in terms of the following capabilities:

- Fast and stable on-line finding and tuning the parameters of the controller with minimum number of iteration in the local and global search.
- Obtaining best torque control action, with small spikes as well as no saturation torque action state for the nonlinear neural controller.
- Minimizing the pose error and no oscillation output for the wheeled mobile robot during motion in the reference path.
- Strong adaptability and robustness performance when dynamic disturbances have been added to the mobile robot.

7. References

[1] Leenaa N. and Sajub K.K., Modelling and Trajectory Tracking of Wheeled Mobile Robots. International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015), vol. 24, Pages 538–545. 2016.

[2] Asif M., Khan M. J., Rehan M. and Safwan, M., Feedforward and Feedback Kinematics Controller for Wheeled Mobile Robot Trajectory Tracking. Journal of Automation and Control Engineering, vol. 3, no.3, pp.178–182. 2015.

[3] Ahmed Al-Araji, Comparative Study of Various Intelligent Algorithms Based Nonlinear PID Neural Trajectory Tracking Controller for the Differential Wheeled Mobile Robot Model. Journal of Engineering vol. 20, no. 5, pp. 44-60. 2014

[4] Khulood E. Dagher and Ahmed Al-Araji, Design of a Nonlinear PID Neural Trajectory Tracking Controller for Mobile Robot based on Optimization Algorithm. Engineering & Technology Journal. Vol. 32, no. 4, pp 973-986. 2014.

[5] Safwan M., Uddin V. and Asif M., Nonholonomic Mobile Robot Trajectory Tracking using Hybrid Controller, Mehran University Research Journal of Engineering and Technology, vol. 35, no. 2, 2016.

[6] Martinez-Soto R., Castillo O., Aguilar L. and Baruch, I, Bio-Inspired Optimization of Fuzzy Logic Controllers for Autonomous Mobile Robots, Fuzzy Information Processing Society (NAFIPS-2012), Annual Meeting of the North American, pp. 1–6, 2012.

[7] Abdallan TY and Hamzah MI, Trajectory Tracking Control for Mobile Robot using Wavelet Network, International Journal of Computer Applications, vol. 74, no. 3, pp. 32-7, 2013.

[8] Ye J., Tracking Control for Nonholonomic Mobile Robots: Integrating the Analog Neural Network into the Backstepping Technique, Neurocomputing, vol. 71, no. 16–18, pp. 3373–3378, 2008.

[9] Hou Z.-G, Zou A.-M., Cheng L. and Tan M., Adaptive Control of an Electrically Driven Nonholonomic Mobile Robot via Backstepping and Fuzzy Approach, IEEE Transactions on Control Systems Technology, vol.17, no.4,pp. 803–815, 2009.

[10] Ahmed Al-Araji, Development of kinematic path-tracking controller design for real mobile robot via back-stepping slice genetic robust algorithm technique. Arabian Journal for Science and Engineering 39 (12), 8825-8835, 2014.

[11] Koubaa Y., Boukattaya M. and Dammak T., Adaptive Sliding-Mode Dynamic Control for Path Tracking of Nonholonomic Wheeled Mobile Robot. Journal of Automation and Systems Engineering vol. 9,no. 2, pp. 119-131, 2015.

[12] Aicha B., Atallah B.1 and Farès B., Integral Sliding Mode Control for Trajectory Tracking of Wheeled Mobile Robot in Presence of Uncertainties, Journal of Control Science and Engineering,
vol.2016, article ID 7915375, 2016.

[13] Ahmed Al-Araji, Maysam Abbod, and Hamed Al-Raweshidy, Neural autopilot predictive controller for nonholonomic wheeled mobile robot based on a pre-assigned posture identifier in the presence of disturbances. 2nd International Conference on Control, Instrumentation and Automation (ICCIA),pp. 326-331, 2011.

[14] Ahmed S. Al-Araji, Maysam F. Abbod and Hamed S. Al-Raweshidy, Design of a neural predictive controller for nonholonomic mobile robot based on posture identifier, Proceedings of the IASTED International Conference Intelligent Systems and Control (ISC). Cambridge, United Kingdom, July 11 - 13, 2011, pp. 198-207, 2011.

[15] D.T. Pham, A. Ghanbarzadeh, E. Koc, S. Otri, S. Rahim and M . Zaidi, The Bees Algorithm. Technical Note, Manufacturing Engineering Centre, Cardiff University, UK, 2005.

[16] D.T. Pham, E. Kog, A. Ghanbarzadeh, S. Otri, S. Rahim, M. Zaidi, The Bees Algorithm – A Novel Tool for Complex Optimisation Problems, IPROMS 2006 Proceeding 2nd International Virtual Conference on Intelligent Production Machines and Systems, Oxford, Elsevier, 2006.

[17] Internet websitehttp://parallax.com/. Robotics with the Eddie Mobile Robot text manual. Accessed Sept. 2016.

تصميم خوارزمية هجينة مدركة لتنغيم مسيطر لاخطي لتتابع مسار لعجلة الإنسان آلي متنقل

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الخلاصة

ان هذا البحث يقدم خوارزمية تنغيم المسيطر المدركة بشكل حي ومتصل للمسيطر اللاخطي لتتابع مسار عجلة الإنسان الآلي الحركي لتباع المسار المستمر المرغوب.ان الهيكلية المقترحة لخوارزمية الامثلية هي الهجينة (النحل مع حشد الجسيمات الامثلية) لايجاد وتنغم قيم كسب المسيطر (العصبي وطريقة الخطوة الراجعة) وتتميز بسرعة وبساطة تقنية التنغيم وبشكل حي ومتصل.

ان افضل عزم مسيطر لعجلة اليمين واليسار لعربة الإنسان الآلي تم توليدها بشكل حي ومتصل من خلال المسيطرين المقترحين. لقد تم إثبات من خلال نتائج المحاكاة أن المسيطر العصبي اللاخطي المقترح مع الخوارزمية الهجينة المدركة هي اكثر دقة من حيث ايجاد وتنغيم عناصر المسيطر بشكل حي ومتصل ويؤدي الى الحصول على فعل سيطرة ناعم فضلاعن تقليل الخطأ ألتتابعي لعجلة الإنسان الآلي مقارنة مع أداء المسيطرة ذات تقنية الخطوة الراجعة.