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Robust Optimization of Routing Robot for Prediction, Estimation and Target Trajectory based on Bat Algorithm

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Abstract

Mobile robots have a wide range of applications in the industry. It is necessary and necessary to determine its errors in parametric and non-parametric indeterminate conditions, as well as to provide a robust controller along with tracking the target in them. Hence, the research has been attempting to provide a controller-based target tracking method for estimating control errors in mobile robots. The proposed method is to use the LQR controller as robust and optimized and use the Bat Algorithm node's observation to calculate and identify control errors. A linear Kalman filter is also used to track targets in a moving robot. The results show that the proposed method has a good performance compared to previous methods.

1. Introduction

Considering that the model of many mobile robot systems with nonlinear dynamical equations is presented, the discussion of the stabilization and control of mobile robot systems is among the most important topics in the field of control. In addition, there is an undeniable existence, which is undeniable because of the change in the parameter over time, whether due to modeling errors or even inadequate measurements. Many systems have a functional limit on the input trigger. Therefore, one of the most important challenges is the control of mobile robot systems, which is a controller design that can ensure the stability of such systems and also drive the system's performance toward a desirable response. Including mobile robot systems, these can include robotic systems for ships and submarines, helicopters, spacecraft, which have many applications in military and industrial sectors. In order to promote the guidance and control of the system, the discussion of the use of intelligent adaptive controls is very much considered [1].

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The highly nonlinear dynamical equations are multivariate and highly computable with heavy coupling between inputs and outputs. In addition, the space model of the system has high volume computing. However, resistant and adaptive control methods have been proposed to overcome uncertainties in order to calculate second-order dynamics errors, but due to the complexity of dynamics, they are faced with a problem. Conversely, the design of classic controllers is easy because of the freedom of the model. However, it is difficult to prove the stability of all-directional robot systems [2]. A system can be used as a general approximation for the approximation of any nonlinear function. This feature of systems has been used in the design of adaptive controllers [3]. One of the main topics of this research is the use of mobile robots, the main purpose of which is to calculate its second-order dynamics error using dynamic equations. It is necessary to make a cognition about the moving robot. A great deal of variation in the contradictory requirements, such as speed, complexity, maneuverability, flexibility and potency, leads to a large variety of mechanisms provided as a response [4].

The most important part of any movable robot is the displacement system that determines the robustness and robustness of the robot while moving on the ground. The choice of each method depends on the design requirements such as the height of the obstacles, the stability criterion and the surface friction coefficient, and there is no single answer to evaluate the displacement methods. The purpose of tracking movable targets based on the linear Kalman filter in a moving robot is to estimate the error, which is capable of maintaining the proper position and also to detect the error convergence to zero in the presence of indeterminate parameters, the Bat Algorithm based on the design of tracking tracing targets for the robot in order to unit A controller has been used. The design of the proposed control system consists of two steps, which include controller design and Bat Algorithm design. In order to design the controller, the indeterminate parameters, Columbus and viscous friction, and also nonlinear, with a strong reaction, should be observed and analyzed for non-modeling dynamics. One of the most important reasons why a Bat Algorithm is used is to estimate, in addition to states, the changes made to the goals. These changes are due to internal and external disturbances, the most important of which is the occurrence of an error, which is considered one of the most important parameters of this research. To do this, we must first identify the governing equations of the system and then design the appropriate controller for the model. In this case, the controller model will be modified to improve the performance of the closed loop system in the face of the changes. Hence, the system is in a comparative control. Also, the use of the LQR controller as a functional controller will be used in this research [5, 6].

It is necessary to obtain an acceptable kinematic model to determine the position, direction of the robot, control and track of its path. In addition, since the robot has limited energy, the efficient activation of the wheels will be helpful with reverse kinematics to save the robot's energy in a long path. Therefore, calculating the dynamic error of the second order robot is necessary. The use of a variety of predictive and estimating methods is used in this area. One of these methods can be Kalman filters that have different types. The method used in this research is to use the linear Kalman filter. Due to the fact that other Kalman filters, such as Kalman filter, extended Kalman filter, Kalman filter without odor, Kalman particle filter and other hybrid models, have not been used in this study, and the Kalman filter method has been considered, the lower computational volume of this method is. The controller is LQR. Also, the use of a Bat Algorithm for different variations and comparisons with the general bat reflection is one of the goals of this research. It is worth noting that the control error based on the torque at time and the estimate of the deviation error when using the LQR controller is based on the linear Kalman filter that Bat Algorithm is sitting on. Input disturbance along with deviation in motion is considered as the two main parameters in error detection. Parametric indeterminants also play a significant role. This bat reflection actually does the job of estimating errors. In that way, it traverses the path to detect deviant errors.

2. Literature Review

Due to the increasing spread of space science and communications, many researchers have examined the problem of automatic tracking of the target from different aspects. The radar tracking system generally determines the direction of the missile towards the target based on the energy emitted from the targets. These systems are often confronted with a real target diagnosis in the face of misleading fighter action in destroying information that has an impact on the production of guidance commands. In general, routing in missiles can be divided into flat routing, hierarchical routing, and routing of a network-dependent location. This research uses a routing method based on network structure.

Each missile needs a controller to predict the movement. It is necessary to control a system, collect information, process it and issue appropriate commands to the operating units that drive the system [7]. The type of controller of a missile is comparative in that there are generally three types of comparative controllers that include the benefit tabulation, comparative control of the reference model and self-regulating regulators [7]. This research uses self-regulating regulators.

Machine Learning methods are used to carry out routing operations and to predict mobile robot movement and tracking. Learning the machine as one of the most extensive and widely used artificial intelligence branches, arranges and explores the methods and algorithms by which computers and systems can learn; computer programs can over time, improve their performance based on received data [8]. One of the methods that are considered in the routing and tracking of missiles which are part of the machine learning family are evolutionary algorithms and subsets of these swarm intelligence algorithms. Swarm intelligence is a systematic property in which the agents collaborate locally and the collective behavior of the entire agent leads to a convergence at a point close to the optimal global answer. The strength of these algorithms is the absence of a global control [9-11]. The method used by this research as the swarm intelligence algorithm to predict the movement and to achieve the main goals of the research is the Bat Algorithm.

3. Proposed Model

In the method for tracking the moving robot, there are basically methods that can be referred to as complex switching dynamics, unmodulated dynamic, interconnected input-output pair as input vector of time-varying disorder, which is done with approximation on line and moment. In the proposed model, the coordinate frame on the ground is fixed and the coordinated frame is fixed in the robot's geometric center. The matrix of coordinate transfer from the coordinated frame to the moving ground frame is calculated as (1).

$$ {}_{M}^{W}R = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{1} $$

Equation (1) leads to the production of equation (2).

$$ \dot{q} = {}_{M}^{W}RV_M \tag{2} $$

Dynamic model of the moving robot includes the dynamics of the engine as an equation (3).

$$ M_1V_M + C_1V_M = B_1u \tag{3} $$

M_1, C_1 and B_1 are obtained from equation (4) to (6) which equation (6) is fitness function.

$$ M_1 = \begin{bmatrix} \frac{3}{2}\beta_0 + m & 0 & \beta_0\left(-\frac{L_1 + L_2 - 2L_3}{2}\right) \\ 0 & \frac{3}{2}\beta_0 + m & \frac{\sqrt{3}}{2}\beta_0 + (L_1 - L_2) \\ \beta_0\left(-\frac{L_1 + L_2 - 2L_3}{2}\right) & \frac{\sqrt{3}}{2}\beta_0 + (L_1 - L_2) & \beta_0(L_1^2 + L_2^2 + L_3^2) + I_v \end{bmatrix} \tag{4} $$

$$ C_1 = \begin{bmatrix} \frac{3}{2}\beta_1 & -m\dot{\theta} & \beta_1\left(-\frac{L_1 + L_2 - 2L_3}{2}\right) \\ m\dot{\theta} & \frac{3}{2}\beta_1 & \frac{\sqrt{3}}{2}\beta_2 + (L_1 - L_2) \\ \beta_1\left(-\frac{L_1 + L_2 - 2L_3}{2}\right) & \frac{\sqrt{3}}{2}\beta_1 + (L_1 - L_2) & \beta_1(L_1^2 + L_2^2 + L_3^2) \end{bmatrix} \tag{5} $$

$$ B_1 = \beta_2 \begin{bmatrix} -\frac{1}{2} & -\frac{1}{2} & 1 \\ \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} & 0 \\ L_1 & L_2 & L_3 \end{bmatrix} \tag{6} $$

According to these equation, $\beta_0 = \frac{n^2 I_0}{r^2}$, $\beta_1 = \frac{n^2}{r^2}(b_0 + \frac{K_t K_b}{R_a})$ and $\beta_2 = \frac{nk_t}{rR_a}.L_i, i = 1,2,3$, the contact radius of each section is assembled. I_v is the moment of the inertial robot around the mass of the robot. r is the wheel's radius. k_t is the torque constant of the engine. K_b Fixed EMF is the back of the engine. R_a is the resistance of the motor rod and n is the gear reduction ratio. L_i is calculated from equation (7).

$$L_i = \begin{cases} D_{in}, & if \frac{\pi}{8} + \frac{n\pi}{2} < \emptyset_i \leq \frac{3\pi}{8} + \frac{n\pi}{2} \\ D_{out}, & if -\frac{\pi}{8} + \frac{n\pi}{2} < \emptyset_i \leq \frac{\pi}{8} + \frac{n\pi}{2} \end{cases} n = 0, \mp 1, \mp 2, \mp 3, \dots \quad (7)$$

According to (7), $\emptyset_i$ is the angular position of the wheel i. D_{in} is the internal call radius and D_{out} is the external call radius. The control input $u = [u_1\ u_2\ u_3]^T$ is a supply voltage for the three motors calculated from the two equations (8) and (9).

$${}_M^W R^{-1} = {}_M^W R^T \quad (8)$$

$$\frac{d}{dt} {}_M^W R^{-1} = -{}_M^W R^{-1} {}_M^W \dot{R} {}_M^W R^{-1} \quad (9)$$

The dynamics model of the robot in the coordinate frame on the ground is computed from the combination of equations (1), (2), (8) and (9) in the form of equation (10).

$$M\ddot{q} + C\dot{q} = Bu \quad (10)$$

Which according to equation (10), the relations $M = M_1 {}_M^W R^T$, $C = \frac{M_1 d}{dt} {}_M^W R^T + C_1 {}_M^W R^T$ and $B = B_1$ Is established. It should be noted that wheel slip in the direction of pull force is assumed to be ignored. With this assumption, it can be deduced that by Newton's law, the dynamics of the mobile robot is consistent with the conditions and relations. In total, it can be said that there are two types of coordination systems in the dynamic modeling of the mobile robot. Land frame (X, Y) that are fixed in motion locally, and the surface coordinate system, the body frame being (X_b, Y_b) attached at the center of the moving robot. By considering Newton's law, we can write (10) as (11).

$$F - \begin{bmatrix} cos\emptyset & -sin\emptyset & 0 \\ sin\emptyset & cos\emptyset & 0 \\ 0 & 0 & 1 \end{bmatrix} f_m \quad (11)$$

According to equation (11), $F - [F_x\ \ F_Y]^T$ is an agent vector applied to the center of gravity of the mobile robot in the ground coordination system. Also, $f_m - [f_x\ \ f_Y]^T$ is the vector of the factor that is applied to the center of gravity of the moving robot in the slave coordination system. Considering Newton's second law and factor analysis, the dynamics of the moving robot will be in the form of relation (12).

$$Dynamic = \begin{cases} f_x - V_1 - \frac{1}{2} V_2 - \frac{1}{2} V_3 \\ f_y - 0 + \frac{\sqrt{3}}{2} V_2 - \frac{\sqrt{3}}{2} V_3 \\ M - (V_1 + V_2 + V_3) L \end{cases} \quad (12)$$

According to the speed of the wheels in the moving robot and analysis of the assembly of the wheels, the angular velocity of the moving robot will be in the form of relation (13).

$$Angular\ Speed = \begin{cases} r\omega_1 - \dot{X}_b + L\emptyset \\ r\omega_2 - -\frac{1}{2}\dot{X}_b + \frac{\sqrt{3}}{2}\dot{Y}_b + L\emptyset \\ r\omega_3 - -\frac{1}{2}\dot{X}_b - \frac{\sqrt{3}}{2}\dot{Y}_b + L\emptyset \end{cases} \tag{13}$$

The dynamics of the DC motor is also in the relationship of (14) and (15).

$$\tau - K_t i_a \tag{14}$$

$$u - R_a i_a + K_{emf}\omega_i \tag{15}$$

DC motor dynamic model is generally calculated from the dynamics (16) with regard to the relationship along control torque, output factor, kinematic equations of the mobile robot and motor parameters.

$$DC_{dynamic} = \begin{cases} \ddot{X} - a_1\dot{X} + 2b_1 cos\emptyset u_1 + \left(-b_1 cos\emptyset - \sqrt{3}b_1 sin\emptyset\right)u_2 + \left(-b_1 cos\emptyset + \sqrt{3}b_1 sin\emptyset\right)u_3 \\ \ddot{Y} - a_2\dot{X} + 2b_2 cos\emptyset u_1 + \left(-b_2 sin\emptyset - \sqrt{3}b_2 cos\emptyset\right)u_2 + \left(-b_2 sin\emptyset + \sqrt{3}b_2 cos\emptyset\right)u_3 \\ \ddot{\emptyset} - a_3\emptyset + b_3u_1 + b_3u_2 + b_3u_3 \end{cases} \tag{16}$$

In order to control the adaptation of a robot that has a robot position that is able to maintain a suitable position, as well as to detect the error convergence to zero in the presence of indeterminate parameters, the Bat Algorithm-based LQR controller is based on the design of tracking tracking targets for the robot for the controller unit O, has been used. The design of the proposed control system consists of two steps, which include LQR controller design and Bat Algorithm design.

In order to design the controller, according to equation (10), indeterminate parameters, silicone and sticky friction, as well as non-linear, with a strong reaction, are not modeled and not included in the dynamics, are observed and analyzed. Considering this unmodified robot dynamics, Robot dynamics model is re-rewritten as Equation (10) in the form of relation (17).

$$\ddot{q} = -M^{-1}\left(C\dot{q} + w(t)\right) + (M^{-1}B - M_0^{-1}B_0)u + M_0^{-1}B_0u \tag{17}$$

According to equation (17), $w(t)$ is an unknown vector of 3×1, which addresses the unmodified dynamic representation. $M_0^{-1}B_0$ The estimate $M^{-1}B$ has been eliminated in the switching information. The switching information in $M^{-1}B$ remains as $(M^{-1}B - M_0^{-1}B_0)$. Therefore, all the complex switching dynamics are $-M^{-1}\left(C\dot{q} + w(t)\right) + (M^{-1}B - M_0^{-1}B_0)u +$

$M_0^{-1}B_0u$ will be. By determining $q_d = [x_d\ \ y_d\ \ \theta_d]^T$ as the proper robot tracing, the nominal system is derived from equation (18).

$$\ddot{q}_d = -M_d^{-1}\big(C_d\ddot{q}_d + w_d(t)\big) + (M_d^{-1}B - M_{0d}^{-1}B_0)u_d + M_0^{-1}B_0u_d \tag{18}$$

Which according to equation (18), $M_d = M(q_d)$, $M_{0d} = M_0(q_d)$, $C_d = C(q_d, \dot{q_d})$, $w_d = w(q_d, \dot{q_d})$ and u_d are nominal control inputs . By determining $e = q - q_d$, the dynamic equation of the tracking error will be in the form of relation (19).

$$\begin{aligned}\ddot{e} = \ddot{q} - \ddot{q}_d = M_d^{-1}B_0u - M^{-1}\big(C\dot{q} + w(t)\big) + (M^{-1}B - M_d^{-1}B_0)u - M_{0d}^{-1}B_0u_d \\ + M_d^{-1}\big(C_d\dot{q_d} + w_d(t)\big) - (M_d^{-1}B - M_{0d}^{-1}B_0)u_d\end{aligned} \tag{19}$$

By relation (20) with respect to f, we can have relation (21).

$$\begin{aligned}f = -M^{-1}(\big(C\dot{q} + w(t)\big) + (M^{-1}B - M_d^{-1}B_0)u - M_0^{-1}B_0u_d \\ + M_d^{-1}\big(C_d\dot{q_d} + w_d(t)\big) - (M_d^{-1}B - M_{0d}^{-1}B_0)u_d\end{aligned} \tag{20}$$

$$\ddot{e} = f + M_d^{-1}B_0u \tag{21}$$

According to equation (21), $f = \big[f_x(t)\ \ f_y(t)\ \ f_\theta(t)\big]^T$ is the input vector of the variable disruption in unknown time in three channels, which includes all the complex dynamics of the robot switching, nonlinearity, and unmodified dynamics which is based on the interference effects of the input-output pair. It should be noted that f is discontinuous when switching dynamics is involved. To apply the control conditions, the $\hat{f}$ value is defined as the estimate f, which leads to relation (22).

$$u = (M_d^{-1}B_0)^{-1}(-\hat{f} + u_0) \tag{22}$$

With the assumption that f is well estimated, the nonlinear MIMO tracking error dynamically switches to the three SISO pairs of the complex, whose relation is given by (23).

$$\ddot{e} \approx u_0 \tag{23}$$

The LQR controller is applied to the three-channel integral error integral dynamics, which is the relation (24).

$$u_0 = -K_p(q - q_d) - K_d(\dot{q} - \dot{q}_d) = -k_pe - K_d\dot{e} \tag{24}$$

The combination of (22) and (24) leads to the production of a controlling law such as (3-26).

$$u = (M_d^{-1}B_0)^{-1}(-\hat{f} - K_pe - K_d\dot{e}) \tag{25}$$

The combination of (23) and (25) also leads to the production of relation (26), which is the dynamical equation of the closed loop error.

$$\ddot{e} + K_d\dot{e} + K_p e = \tilde{f} \tag{26}$$

In accordance with equation (26), $\tilde{f} = f - \hat{f}$ is the estimated error of the input of the disorder during the variable f. Since the choice of K_d and K_p leads to the production of a result in the dynamic system, a linear disturbance error is stable. Under limited assumptions $\tilde{f}$, the limited limited-output input reliability for a fault-tolerant system is assured. In addition, the error rate is proportional to the upper limit $\hat{f}$, according to equation (26), which is multiplied by the inverse of the integer value of the smallest real part of the root.

Once the LQR controller is designed to be robust, we will have Bat Algorithm. As noted above, the simplification of the above system is based on the assumptions that the input vector of the variable disturbance at time f can be estimated well. In this section, the Bat Algorithm is created to estimate f. Since a discontinuous function is approximated by equations, curves, etc., it is logical to assume that the degree of discontinuity f can be corrected with the approximation by the continuous function. The input vector of the disorder of the variable of time f can be approximated by a $(p - 1)$ family of inputs of the Taylor time equations, whose relation is (27).

$$f(t) \approx \sum_{t=0}^{p-1} \alpha_i t^i + r(t) \tag{27}$$

Which according to (27), with respect to $\alpha_i \in \mathbb{R}^3$ as constant coefficients and j 'th derivative of time, is completely uniformly limited by the remainder of $r(t)$. By defining $e_1 = e$, $e_2 = \dot{e}$ and $f_1 = f$, the dynamics of the linear calman filter based on the trace error is written as (28).

$$\begin{aligned} &\dot{e}_1 = e_2 \ , \\ &\dot{e}_2 = M_d^{-1} B_0 u + f_1 \ , \\ &\dot{f}_1 = f_2 \ , \\ &\dots \\ &f_{p-1} = f_p \ , \\ &f_p = r^{(p)}(t) \end{aligned} \tag{28}$$

By specifying $\dot{e}_1$ and $\dot{e}_2$ as the estimates e_1 and e_2, the Bat Algorithm can assume the dynamic equation of error, which is derived as a equation (29). It means that there are two kinds of error estimation which $\dot{e}_1$ is the internal errors and $\dot{e}_2$ is the external errors. f_p is the fitness probability, $r^{(p)}$ is the trace error by Kalman filter and t is the time of tracking. Of course, according to a Kalman filter based on a Kalman filter, this is a consequence of equation (28).

$$\begin{aligned} &\hat{e}_1 = \hat{e}_2 + \lambda_p +_1 \tilde{e} \ , \\ &\hat{e}_2 = M_0 B_0^{-1} u + \hat{f}_1 + \lambda_p \tilde{e} \ , \\ &\hat{f}_1 = \hat{f}_2 + \lambda_p -_1 \tilde{e} \ , \\ &\dots \\ &\hat{f}_{p-1} = \hat{f}_p + \lambda_1 \tilde{e} \ , \\ &\hat{f}_p = \lambda_0 \tilde{e} \end{aligned} \tag{29}$$

According to equation (29), $\tilde{e} = e - \hat{e}_1$, λ_i and $i = 0,1,2,\dots p + 1 \epsilon \mathbb{R}^{3\times3}$ are observed values. $\hat{f}_i$ is the approximation $f_i, i = 1,2,\dots p.p$, which is the Bat Algorithm arrangement. The choice of λ_i assures that the polarization of the detector error in the three channels is in an appropriate position. The characteristic dynamic equation of the bat reflection error is separated as the relation (30).

$$\eta(s) = s^{p+2}I + \lambda_p +_1 s^{p+1} + \cdots + \lambda_1 s + \lambda_0 \quad (30)$$

Which is the class of relation (30), $\eta(s) \in \mathbb{R}^{3\times3}$. For simplicity, all poles in the three channels are in the same position as the relation (31).

$$\eta(s) = (s + \omega_0)^{p+2}I \quad (31)$$

Which according to (31), $\omega_0(\omega_0 > 0)$ is a parametric parameter for determining the appropriate poles. Then the Bat Algorithm can easily be obtained by comparing two relationships (30) and (31). A higher degree of Bat Algorithm results in better estimation of the performance of the disorder, and especially the variable disorder.

4. Simulation and Results

In order to move the robot in all directions in the presence of parametric and non-parametric indeterminacy, the sample time is important for running the movements. This time is equal to 0.001 seconds. LQR controller training time is also 500. It is also important to obtain a current time error that is set with the k variable. The current time error is when the robot moves at any moment. The previous time error is the same error that the robot crosses the path, but the error remains. Normal conditions should be less than one minute, so that the robot can perform controller operations in the presence of parametric and non-parametric indeterminations. The previous time error is also obtained as $k + 1$. The value of M is 500, which includes the dynamic model of the robot. The coordinate transfer matrix of the coordinated frame movable to the moving ground frame for sin and cos is defined as follows:

Sin[q(3)) 0 0 1];

Where q is actually the output of the transmission matrix whose value is [1; 0; pi / 2]; the cos value is as follows from sin.

0.10*[cos(q(3)) sin(q(3)) 0; 0 0 1];

The total number of robot targets is 10 in the path. The robot's moment of inertia around the center of the robot's mass is 18.3 and the robot wheel radius is 9.49. The routing error is also 0.8. The fixed EMF of the engine's rear is also 50 and the torque constant of the engine is also considered 100. Bat Algorithm goals in the environment are as follows:

Bat_Targets=[1 Targets_No 0 0;0 1 0 0;0 0 1 Targets_No;0 0 0 1];

That means Targets_No is the same number of general robot targets that are assumed to be 10. The supply voltage for the three engines is assumed as follows:

h=[1 0 0 0;0 0 1 0];

When the robot starts moving, it will be in shown as Fig. 1.

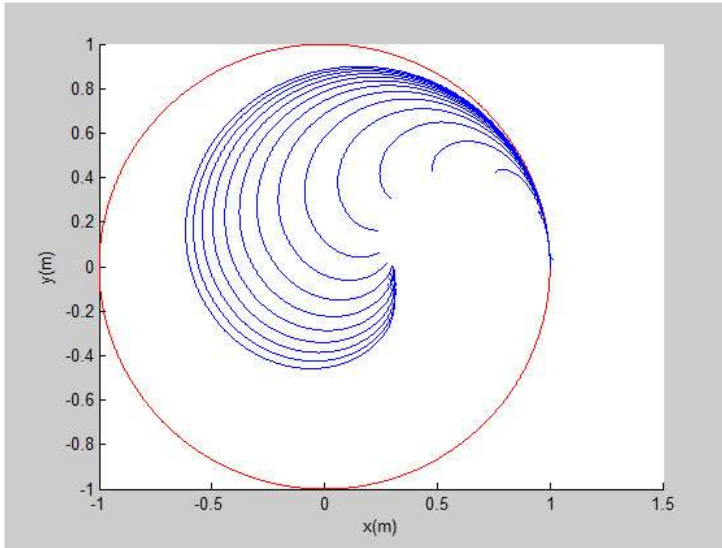

Fig. 1 Robot movement.

As shown in Fig. 1, the starting point of the robot is at the point [0 1], that is, the vertical zero or y (m) and the horizontal one, or x (m). The robot starts in all directions, which can be seen in the presence of parametric and nonparametric in determinants in Fig. 2.

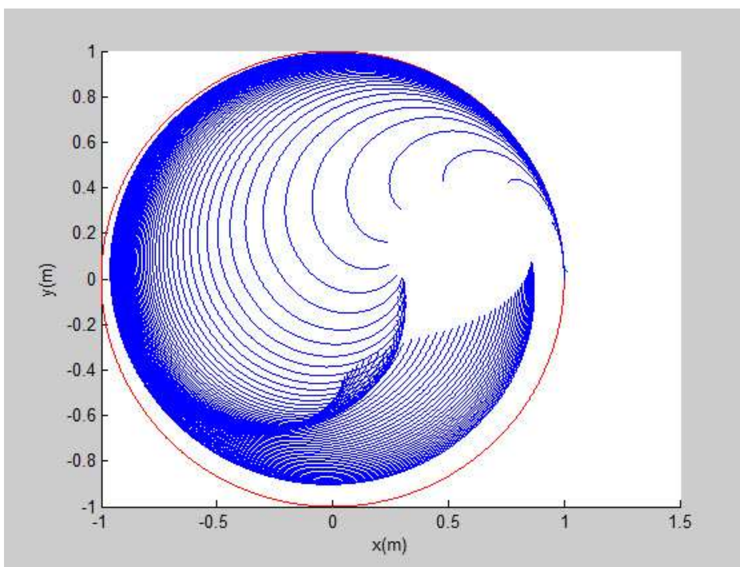

Fig. 2 Robot movements during work in all directions

The meaning of these indeterminants is the presence of noise, clutter, jamming and any other turmoil in the path. When the parametric and nonparametric indices end, robot control ends. That is, any disturbances are lost and the path is correctly identified, which can be seen in the end result in Fig. 3.

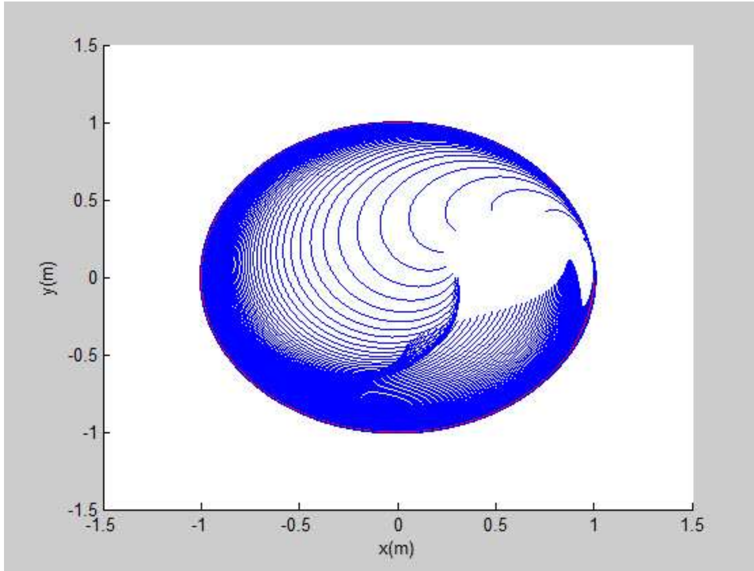

Fig. 3 Robot termination

As shown in Fig. 3, the robot has traversed all the paths in the parametric and nonparametric indeterminacy. In Fig. 4, robot motions can be seen outside parametric and nonparametric indeterminacy.

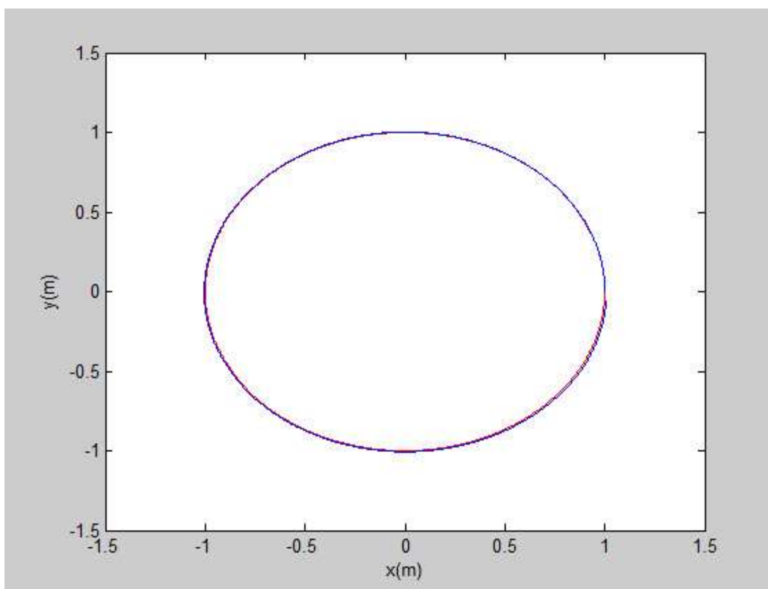

Fig. 4. Robot movements outside parametric and nonparametric indeterminacy

Based on Fig. 4, the path of the robot is determined by the fact that the moving robot around it has moved beyond parametric and nonparametric indeterminacy. The general result of the comparative control of moving robots by determining the error based on the proposed method and comparison with the reference method is shown in Fig. 5.

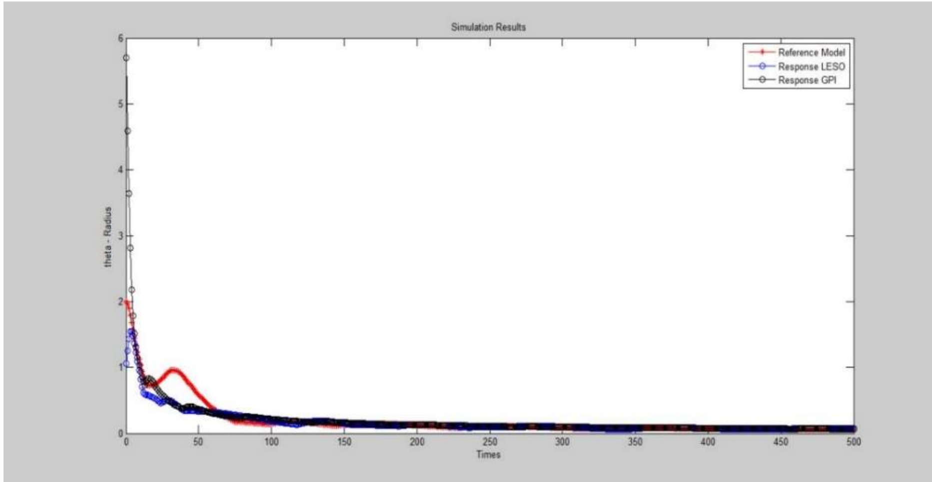

Fig. 5 simulation result and comparison with reference method

As shown in Fig. 5, the result of the Bat Algorithm based LQR controller response relative to the reference model and the LESO method has an angular and parametric improvement in the presence of parametric and nonparametric indices (probability errors). The reference method, without using the proposed method of this research, is based on the linear Kalman filter or LKF, which is known as the classical method. In fact, all sections are deleted and only the LKF method remains the reference method. The execution time of the proposed method is also 87.0320 seconds in a system with 8 GB of memory. In the following, it is necessary to trace the error of the estimation of the parameters along with the control signals. In Fig. 6, the trace error is estimated for torque-to-time parameters based on a linear Kalman filter based robot.

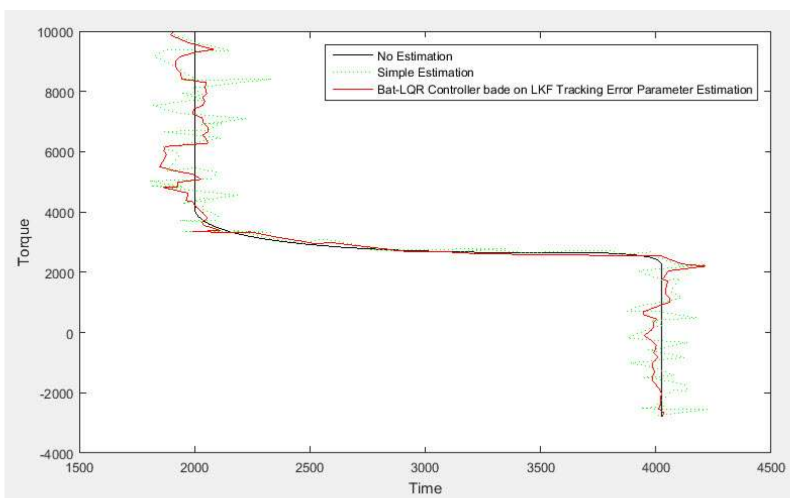

Fig. 6 Trace error estimation of torque-to-time parameters

As shown in Fig. 6, there are three lines in which the black line did not record an estimate, because the robot was static and motionless. Then a simple parametric estimation is performed that is shown with a green graph and finally a trace error is found to estimate the robot's parameters, which is indicated by a green graph. It does not mean that time moves, that is, over time, the torque is moving. Upon completion of the simulation, the mobile robot power consumption is equal to 56.2045 mW, which indicates a good passage. In this research, several evaluation criteria will be used including Mean Square Error[1], Peak Signal to Noise Ratio[2], Signal-to-Noise Ratio[3], and Accuracy criteria. Based on the results of the evaluation criteria after the project implementation, it can be ensured that the proposed method is used to roam the mobile robot and estimate and track the target. The results of the evaluation methods are shown in Table (1) and comparison with other methods represented in Table (2).

Table (1) Results of proposed approach in terms of evaluation criteria

Specificity (%)	Sensitivity (%)	Accuracy (%)	SNR (dB)	PSNR (dB)	MSE
80.07	80.08	96.00	56.0618	9.9310	0.6400

Table (2) Proposed Approach Evaluation Criteria in Comparison to Recent Methods

References	Accuracy (%)
Hujic, Damir, et al., 1998 [16]	87.00 %
Wang, Zhiyuan, et al., 2018 [15]	92.00 %
Proposed Method	96.00 %

5. Conclusion

In this paper, the problem of modeling, simulation and implementation of tracking movable targets based on linear Kalman filter and Bat Algorithm in a moving robot has been investigated. With the help of MATLAB software environment and analysis of dynamic equations of robotic systems, it has particular difficulties. Therefore, the use of software to accelerate the obtaining of equations governing robotic systems is inevitable. The simulation in the MATLAB environment with a variety of toolboxes makes it easy to design control systems. Initially, a variety of robots was introduced to understand the complexity of the equations governing robotic systems. After comparing the analytical solution with the simulation solution, other toolbox capabilities have been investigated. This includes a variety of conventional analytics in robot analysis. Then, the proposed method for estimating error is presented. For future research using firefly algorithm [16] or other metaheuristic algorithm is proposed.

6. References

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[1] MSE
[2] PSNR
[3] SNR

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