AENSI Journals
Australian Journal of Basic and Applied Sciences
ISSN:1991-8178
Journal home page: www.ajbasweb.com

Model Predictive Control based reference point tracking of quad-rotor UAV in prevalence of disturbance

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ARTICLE INFO
Article history:
Received 20 November 2013
Received in revised form 24 January 2014
Accepted 29 January 2014
Available online 5 April 2014

Key words:
Quad-rotor UAV, Reference point tracking, Model Predictive Control.

ABSTRACT
This paper presents an accomplishment of reference point tracking with the help of Model predictive control (MPC). The foremost concern is based upon predicting the performance of the system in occurrence of unknown disturbances and also reveals the effectiveness for the disturbance problem on Quad-rotor type Unamnned Aerial Vehicles (UAV), while tracking to its reference point. MPC performance and its effectiveness are verified through simulations on MATLAB.

To Cite This Article: M. Hassan Tanveer, D. Hazry, S. Faiz Ahmed, M. Kamran Joyo, Faizan. A. Warsi, Zuradzman M. Razlan, Khairunizam Wan, A.T. Hussain, Model Predictive Control based reference point tracking of quad-rotor UAV in prevalence of disturbance. ***Aust. J. Basic & Appl. Sci.****, 8(4): 428-431, 2014*

INTRODUCTION

UAVs have gained enormous commercial potential during the last years. The quad-rotor has become the most prominent amongst the researchers as they are capable of maneuvering efficiently. Furthermore, use of UAVs has been visualized in a variety of applications (i.e: environmental protection, natural risk management, remote inspections, rescue missions, agriculture and commercial video production etc). However this type of rotorcraft UAV carries severe issues regarding its aerodynamic controls which is responsible of its unstable performance and requires an effective controller. This article tells one of the most promising accomplishments towards autonomous UAV for reference point tracking with the help of MPC.

In the past couple of years reference tracking of quad-rotor has remained an issue due to the kinematic constraints and unstable dynamics which makes quad-rotor UAV non-linear in nature. However some of the control techniques have been developed in this area. In 2013 Adaptive Hybrid Control Algorithm Design for Quad-rotor UAV (Hazry, 2013). In 2007, the control objective of the NMPC is determined to track a desired line in (Kang, 2007).

In 2003 Richards, evaluated the formation of UAV to fly several way points with the help of MPC (Richards, 2003). In 2006, Ozguner used sliding mode and PID control for the system (Xu, 2006). In 2007, Samir Bouabdullah and Ronald Siegwart used a Backstepping method for controlling of a quad-rotor, the results of this technique showed a flexible control structure (bouabdullah, 2007). This paper focuses on proposed control technique that is based on MPC for reference tracking. The proposed algorithm is simulated on (MATLAB).

The contribution is organized as follows: the modeling of the quad-rotor is recalled in Section 2 and a predictor based controller for reference tracking is introducing in same section. Simulations and experimental results for the system in closed-loop with the control/predictor are presented in Section 3. Concluding remarks are given in Section 4.

MATERIAL AND METHODS

A. Modelling:

The equation of motion are extracted from the Newton Euler method. Equation 1 is the overall position and orientation dynamics of quad-rotor UAV which is discussed comprehensively in my previous article (Tanveer, 2013).

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$$\begin{cases} \ddot{X} = (\sin\psi \sin\phi + \cos\psi \sin\theta \cos\phi)\frac{U_1}{m} \\ \ddot{Y} = (-\cos\psi \sin\phi + \sin\psi \sin\theta \cos\phi)\frac{U_1}{m} \\ \ddot{Z} = -g + (\cos\theta \cos\phi)\frac{U_1}{m} \\ \dot{\phi} = \frac{I_{YY} - I_{ZZ}}{I_{XX}}\theta\psi - \frac{J_{TP}}{I_{XX}}\theta\omega + \frac{U_2}{I_{XX}} \\ \dot{\theta} = \frac{I_{ZZ} - I_{XX}}{I_{YY}}\theta\psi - \frac{J_{TP}}{I_{YY}}\theta\omega + \frac{U_3}{I_{YY}} \\ \dot{\psi} = \frac{I_{XX} - I_{YY}}{I_{ZZ}}\theta\psi - \frac{U_4}{I_{ZZ}} \end{cases} \quad (1)$$

$$\begin{cases} U_1 = b({\omega_1}^2 + {\omega_2}^2 + {\omega_3}^2 + {\omega_4}^2) \\ U_2 = lb(-{\omega_2}^2 + {\omega_4}^2) \\ U_3 = lb({\omega_1}^2 + {\omega_3}^2) \\ U_4 = d(-{\omega_1}^2 + {\omega_2}^2 - {\omega_3}^2 + {\omega_4}^2) \end{cases}$$

Where ‘l’ is the distance between the center of the quad-rotor and the center of a propeller. U1, U2, U3 and U4 are the movement vector components. Their relation with the propellers’ speeds comes from aerodynamic calculus (Joyo, 2013).

B. Controller Design:

Fig. 1 shows the arrangement of MPC with plant of the same system evaluated in this article. The plant consists of all necessary equations required to follow the reference point in equation 1. The whole structure in Fig. 1 explains that two inputs are inflowing in plants which are measured disturbance and set-points. Whether, in MPC three inputs are inward bounding which is addition of feed-back signal coming from plant.

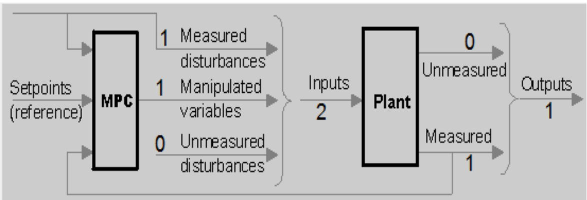

Fig. 1: Structure

MPC as the name recommend it calculate the future assessment of the system and organize the control action accordingly. It predicts control future signal in such a manner that it reduces a define cost function which is an error signal between the output and desire tracking point over particular prediction horizon. MPC starts predicting the future control action by choosing the suitable values of control horizon M, prediction horizon P and control-weighting factor R.

Thus the objective function for system can be formulated by taking into account the dynamics of system that can be expressed as stated in given in equation (2):

$$x\ (k + 1) = Ax(k) + B\ u\ (k) \quad (2)$$

Prediction Horizon length N:

$$x(k) = \begin{bmatrix} x\ (k+1\ |k) \\ x\ (k+N\ |k) \end{bmatrix}$$

$$u(k) = \begin{bmatrix} u(k\ |k) \\ u\ (k+N-1\ |k) \end{bmatrix}$$

and the estimation error is an additive term, applied at each time step, the error is uniformly distributed in every feedback.

$$x\ (k + i + 1 \mid k) = Ax(k + i \mid k) + B\ u\ (k + i \mid k) \quad (3)$$

x(k) = M x(k) + C u(k)
is the state prediction.

The optimization cost function is then become:

$$J(k)=\sum_{i=0}^{N-1}[x^T(k+i\,|\,k)Qx(k+i\,|\,k)+u^T(k+i\,|k)\,Ru(k+i\,|\,k)+x^T(k+N|k)\bar{Q}x(k+i|k)]$$

Where Q and $\bar{Q}$ are weight coefficient. Evaluating all above equations in J.

RESULT AND DISCUSSION

Simulation results are presented in this section to validate the performance of MPC in occurrence of unwanted disturbance. The control law aims is to reach reference point, which is in given scenario to reach amplitude of value 2. From Fig. 2 it is clearly evaluated that the disturbance added to system is around 200% of the reference path.

First, the need is to specify horizons so the chosen robust horizon parameters of MPC are shown in table 1, prediction horizon is for capturing the major dynamics of plant so it has to be long enough because of this selected values of controller the disturbance effect almost become negligible as shown in Fig. 3, results appraise the effect of MPC while disturbance added to reference path.

Table 1: MPC Horizon parameter

Parameter	Value
Control Interval	0.2
Prediction Horizon	10
Control Horizon	2

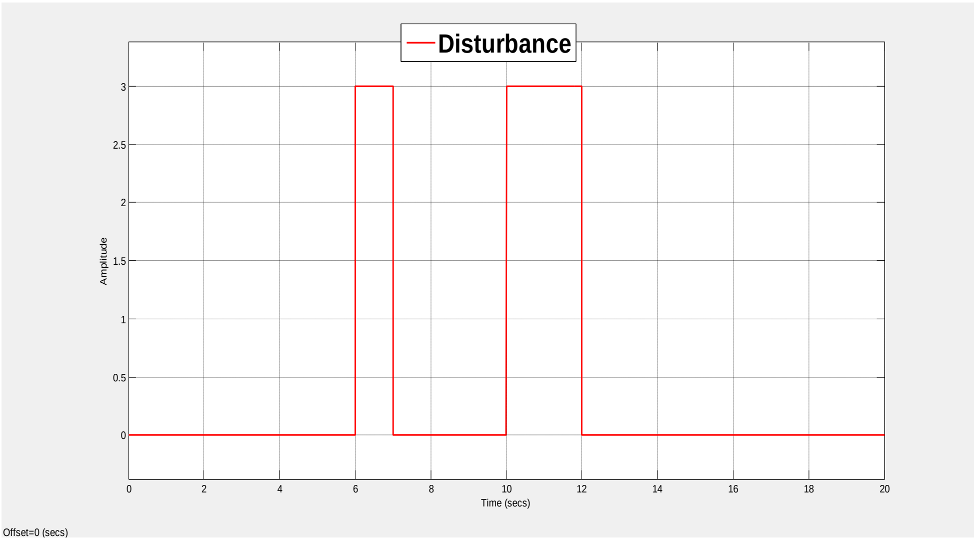

Fig. 2: Disturbance

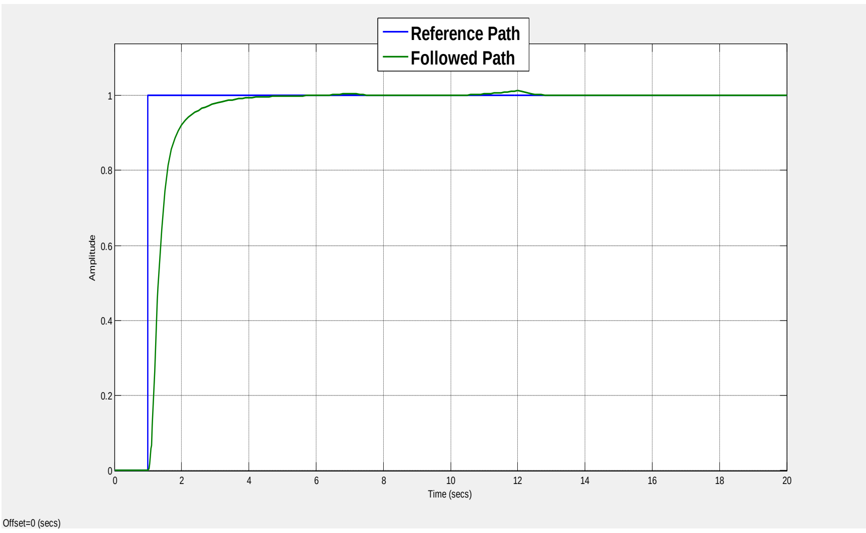

Fig. 3: Reference path and MPC effectiveness

Conclusion:

It can be concluded with the help of this control technique, that once MPC completes its prediction process, it comply best control action and then at the next sampling interval its control estimation is repeated again with the new available information. As a result, the performance of the system becomes increased and stable. The performance of the proposed control design has been ascertained using simulation.

REFERENCES

Conference Proceedings: R. Xu and u. Ozguner, 2006. “Sliding mode control of a quad-rotor helicopter,” Proc. of the 45th IEEE conference on decision and control, pp: 4957-496.

Conference Proceedings: Richards, A., 2003. “Model predictive control of vehicle maneuvers with guaranteed completion time and robust feasibility”, American Control Conference, 2003. Proceedings of the 2003, 5: 4034-4040.

Conference Proceedings: Samir bouabdullah, 2007. “Full Control of a Quad-Rotor,” Proc of IEEE international conference on intelligent robots and systems.

Journal Articles: Chao, H., Y. Cao & Y. Chen, 2010. Autopilots for small unmanned aerial vehicles: a survey. International Journal of Control, Automation and Systems, 8(1): 36-44.

Journal Articles: D.Hazry, S.Faiz Ahmed, 2013. “Adaptive Hybrid Control Algorithm Design for attitude stabilization Of Quad-rotor UAV”, archives Des Science Journal, 66: 2.

Journal Articles: Hsu, Cheng-Kuei, *et al*., 2010. "Development of Flapping Wing Micro Air Vehicles–Design, CFD, Experiment and Actual Flight." Proceedings of the 48th AIAA Aerospace Sciences meeting including The New Horizons Forum and Aerospace Exposition, AIAA. Vol. 1018. 2010.New Horizons Forum and Aerospace Exposition, AIAA., 1018.

Journal Articles: M Kamran Joyo, S.F.A., D. Hazry, M. Hassan, Faizan A. Warsi, 2013. Position Controller Design for Quad-rotor under Perturbed Condition. Wulfenia, 20(7): 178-189.

Journal Articles: Tanveer, M.H., S.F. Ahmed, D. Hazry, M.K. Joyo & F.A. Warsi, 2013. Disturbance And Noise Rejection Controller Design For Smooth Takeoff/Landing And Altitude Stabilization Of Quad-rotor. Journal of Applied Sciences Research, 9(5): 3316-3327.

Journal Articles: Tanveer, M.H., S.F. Ahmed, D. Hazry, F.A. Warsi & M.K. Joyo, 2013. Stabilized controller design for attitude and altitude controlling of quad-rotor under disturbance and noisy conditions. American Journal of Applied Sciences, 10(8): 819.

Journal Articles: Yeonsik Kang, 2007. “Control Systems echnology, IEEE Transactions on”, 17(5): 1202-1210.