A Model Predictive Control (MPC) Approach on Unit Quaternion Orientation Based Quadrotor for Trajectory Tracking

By: Islam, M (Islam, Maidul)[1]; Okasha, M (Okasha, Mohamed)[2]; Sulaeman, E (Sulaeman, Erwin)[1]

INTERNATIONAL JOURNAL OF CONTROL AUTOMATION AND SYSTEMS
Volume: 17 **Issue:** 11 **Pages:** 2819-2832
DOI: 10.1007/s12555-018-0860-9
Published: NOV 2019
Document Type: Article
View Journal Impact

Abstract

The objective of this paper is to introduce with a quaternion orientation based quadrotor that can be controlled by Model Predictive Control (MPC). As MPC offers promising performance in different industrial applications, quadrotor can be another suitable platform for the application of MPC. The present study consistently adopts unit quaternion approach for quadrotor orientation in order to avoid any axes overlapping problem, widely known as singularity problem whereas Euler angle orientation approach is unable to resolve so. MPC works based on the minimal cost function that includes the attitude error and consequently, the cost function requires quaternion error in order to proceed with process of MPC. Therefore, the main contribution of this study is to introduce a newly developed cost function for MPC because by definition, quaternion error is remarkably different from the attitude error of Euler angle. As a result, a unit quaternion based quadrotor with MPC can ascertain a smooth singularity-free flight that is influenced by model uncertainty. MATLAB and Simulink environment has been used to validate the cost function for quaternion by simulating several trajectories.

Keywords

Author Keywords: Constraint handling; cost function; disturbance and noise; path; trajectory tracking; quadrotor; quaternion

Author Information

Reprint Address: Islam, M; Sulaeman, E (reprint author)

Int Islamic Univ Malaysia, Dept Mech Engn, Kuala Lumpur, Malaysia.

Addresses:

[1] Int Islamic Univ Malaysia, Dept Mech Engn, Kuala Lumpur, Malaysia

[2] Int Islamic Univ Malaysia, Dept Mech Engn, Kuala Lumpur, Malaysia

E-mail Addresses: mislam.dipu@gmail.com; mokasha@iium.edu.my; esulaeman@iium.edu.my

Funding

Funding Agency	Grant Number
Malaysian Ministry of Education through International Islamic University Malaysia	FRGS 17-036-0602

View funding text

Publisher

INST CONTROL ROBOTICS & SYSTEMS, KOREAN INST ELECTRICAL ENGINEERS, BUCHEON TECHNO PARK 401-1506, 193 YAKDAE-DONG WONMI-GU, BUCHEON, GYEONGGI-DO 420-734, SOUTH KOREA

Journal Information

Impact Factor: Journal Citation Reports

Categories / Classification

Research Areas: Automation & Control Systems

Web of Science Categories: Automation & Control Systems

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Cited References: 40

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1. ON TRAJECTORY TRACKING MODEL PREDICTIVE CONTROL OF AN UNMANNED QUADROTOR HELICOPTER SUBJECT TO AERODYNAMIC DISTURBANCES **Times Cited:** 43
By: Alexis, K.; Nikolakopoulos, G.; Tzes, A.
ASIAN JOURNAL OF CONTROL Volume: 16 Issue: 1 Pages: 209-224 Published: JAN 2014

2. Title: [not available] — Times Cited: 1
By: [Anonymous].
QP Solver Published: 2018

3. Title: [not available] — Times Cited: 28
By: BANGURA M
IFAC PAPERSONLINE Volume: 47 Pages: 11773 Published: 2014

4. **A tutorial on se (3) transformation parameterizations and on-manifold optimization** — Times Cited: 3
By: Blanco, J.-L.
Tech. Rep Volume: 3 Published: 2010
Publisher: University of Malaga

5. Title: [not available] — Times Cited: 57
By: Bouabdallah, S.
Design and control of quadrotors with application to autonomous flying Published: 2007
Publisher: Ecole Polytechnique Federale de Lausanne

6. **Trajectory tracking and stabilization of a quadrotor using model predictive control of Laguerre functions** — Times Cited: 3
By: Chipofya, M.; Lee, D. J.; Chong, K. T.
Abstract and Applied Analysis Volume: 2015 Article Number: 916864 Published: 2015

7. **Comparison of various quaternion-based control methods applied to quadrotor with disturbance observer and position estimator** — Times Cited: 29
By: Chovancova, A.; Fico, T.; Hubinsky, P.; et al.
ROBOTICS AND AUTONOMOUS SYSTEMS Volume: 79 Pages: 87-98 Published: MAY 2016

8. **Mathematical Modelling and Parameter Identification of Quadrotor (a survey)** — Times Cited: 42
By: Chovancova, Anezka; Fico, Tomas; Chovanec, Lubos; et al.
MODELLING OF MECHANICAL AND MECHATRONIC SYSTEMS Book Series: Procedia Engineering Volume: 96 Pages: 172-181 Published: 2014

9. **Representing Attitude: Euler Angles, Unit Quaternions, and Rotation Vectors** — Times Cited: 124
By: Diebel, J.
Matrix Volume: 58 Pages: 1-35 Published: 2006

10. **Attitude Optimal Backstepping Controller Based Quaternion for a UAV** — Times Cited: 10
By: Djamel, Kaddouri; Abdellah, Mokhtari; Benallegue, Abdelaziz
MATHEMATICAL PROBLEMS IN ENGINEERING Article Number: 8573235 Published: 2016

11. **Flatness-based Control for a Quadrotor Camera Helicopter Using Model Predictive Control Trajectory Generation** — Times Cited: 9
By: Engelhardt, Thomas; Konrad, Thomas; Schaefer, Bjoern; et al.
2016 24TH MEDITERRANEAN CONFERENCE ON CONTROL AND AUTOMATION (MED) Book Series: Mediterranean Conference on Control and Automation Pages: 852-859 Published: 2016

12. **Onboard State Dependent LQR for Agile Quadrotors** — Times Cited: 3
By: Foehn, Philipp; Scaramuzza, Davide
2018 IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION (ICRA) Book Series: IEEE International Conference on Robotics and Automation ICRA Pages: 6566-6572 Published: 2018

13. **Full Quaternion Based Attitude Control for a Quadrotor** — Times Cited: 58
By: Fresk, Emil; Nikolakopoulos, George
2013 EUROPEAN CONTROL CONFERENCE (ECC) Pages: 3864-3869 Published: 2013

14. **Attitude Stabilization of a Quadrotor by Means of Event-Triggered Nonlinear Control** — Times Cited: 16
By: Guerrero-Castellanos, J. F.; Tellez-Guzman, J. J.; Durand, S.; et al.
JOURNAL OF INTELLIGENT & ROBOTIC SYSTEMS Volume: 73 Issue: 1-4 Special Issue: SI Pages: 123-135 Published: JAN 2014

15. **Trajectory tracking of a quadcopter UAV with optimal translational control** — Times Cited: 11
By: Hernandez-Martinez, E.G.; Fernandez-Anaya, G.; Ferreira, E.D.; et al.
IFAC - Papers Online Volume: 48 Issue: 19 Pages: 226-31 Published: 2015

16. **Dynamics and control of quadcopter using linear model predictive control approach** — Times Cited: 1
By: Islam, M.; Okasha, M.; Idres, M. M.
AEROS CONFERENCE 2017 Book Series: IOP Conference Series-Materials Science and Engineering Volume: 270 Article Number: UNSP 012007 Published: 2017

17. **Trajectory tracking in quadrotor platform by using PD controller and LQR control approach** — Times Cited: 2
By: Islam, Maidul; Okasha, Mohamed; Idres, Moumen Mohammad
6TH INTERNATIONAL CONFERENCE ON MECHATRONICS (ICOM'17) Book Series: IOP Conference Series-Materials Science and Engineering Volume: 260 Article Number: UNSP 012026 Published: 2017

18. **Dynamic Visual Sensing based on MPC controlled UAVs** — Times Cited: 1
By: Kanellakis, Christoforos; Mansouri, Sina Sharif; Nikolakopoulos, George
2017 25TH MEDITERRANEAN CONFERENCE ON CONTROL AND AUTOMATION (MED) Book Series: Mediterranean Conference on Control and Automation Pages: 1201-1206 Published: 2017

19. Title: [not available] — Times Cited: 1
By: Kehlenbeck, A.
Quaternion-based Control for Aggressive Trajectory Tracking with a Micro-quadrotor UAV Published: 2014

20. **Survey of Advances in Guidance, Navigation, and Control of Unmanned Rotorcraft Systems** — Times Cited: 300
By: Kendoul, Farid
JOURNAL OF FIELD ROBOTICS Volume: 29 Issue: 2 Pages: 315-378 Published: MAR-APR 2012

21. Title: [not available] — Times Cited: 2
By: Kugelberg, I.
Black-box Modeling and Attitude Control of a Quadcopter Published: 2016

22. Title: [not available] — Times Cited: 2
By: Lindblom, S; Lundmark, A.
Modelling and Control of a Hexarotor UAV Published: 2015

23. **An explicit MPC for quadrotor trajectory tracking** — Times Cited: 4
By: Liu, Cunjia; Lu, Hao; Chen, Wen-Hua
2015 34TH CHINESE CONTROL CONFERENCE (CCC) Book Series: Chinese Control Conference Pages: 4055-4060 Published: 2015

24. **Generalized Nonlinear Optimal Predictive Control using Iterative State-space Trajectories: Applications to Autonomous Flight of UAVs** — Times Cited: 14
By: Murillo, Marina H.; Limache, Alejandro C.; Rojas Fredini, Pablo S.; et al.
INTERNATIONAL JOURNAL OF CONTROL AUTOMATION AND SYSTEMS Volume: 13 Issue: 2 Pages: 361-370 Published: APR 2015

25. Title: [not available] — Times Cited: 1
By: Ostafew, C J.
Learning-based Control for Autonomous Mobile Robots Published: 2016
Publisher: Doctor of Philosophy, University of Toronto, Canada

26. **A novel fully quaternion based nonlinear attitude and position controller** — Times Cited: 3
By: Parwana, H; Patrikar, J S; Kothari, M.
2018 AIAA GUID NAV C Pages: 1587 Published: 2018

27. **LQR Control for a Quadrotor using Unit Quaternions: Modeling and Simulation** — Times Cited: 43
By: Reyes-Valeria, Elias; Enriquez-Caldera, Rogerio; Camacho-Lara, Sergio; et al.
2013 23RD INTERNATIONAL CONFERENCE ON ELECTRONICS, COMMUNICATIONS AND COMPUTING (CONIELECOMP) Book Series: International Conference on Electronics Communications and Computers CONIELECOMP Pages: 172-178 Published: 2013

28. **Decentralized Backstepping Control of a Quadrotor with Tilted-rotor under Wind Gusts** — Times Cited: 2
By: Saif, Abdul-Wahid A.; Aliyu, Abdulrahman; Al Dhaifallah, Mujahed; et al.
INTERNATIONAL JOURNAL OF CONTROL AUTOMATION AND SYSTEMS Volume: 16 Issue: 5 Pages: 2458-2472 Published: OCT 2018

29. **Navigation and Cooperative Control Using the AR.Drone Quadrotor** — Times Cited: 11
By: Santana, Lucas Vago; Brandao, Alexandre Santos; Sarcinelli-Filho, Mario
JOURNAL OF INTELLIGENT & ROBOTIC SYSTEMS Volume: 84 Issue: 1-4 Special Issue: SI Pages: 327-350 Published: DEC 2016

30. **Quaternion Based Adaptive Control for Package Delivery using Variable-Pitch Quadrotors** — Times Cited: 3
By: Shastry, Animesh Kumar; Bhargavapuri, Mahathi T.; Kothari, Mangal; et al.
2018 INDIAN CONTROL CONFERENCE (ICC) Pages: 340-345 Published: 2018

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