Lecture Notes in Electrical Engineering 365

Felix Pasila
Yusak Tanoto
Resmana Lim
Murtiyanto Santoso
Nemuel Daniel Pah
Editors

Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)

Springer

Lecture Notes in Electrical Engineering

Volume 365

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ISSN 1876-1100 ISSN 1876-1119 (electronic)
Lecture Notes in Electrical Engineering
ISBN 978-981-287-986-8 ISBN 978-981-287-988-2 (eBook)
DOI 10.1007/978-981-287-988-2

Library of Congress Control Number: 2015960766

Printed on acid-free paper

This Springer imprint is published by SpringerNature
The registered company is Springer Science+Business Media Singapore Pte Ltd.

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Introduction

This book includes the original, peer-reviewed research papers from the 2nd International Conference on Electrical Systems, Technology and Information (ICESTI 2015), held during 9–12 September 2015, at Patra Jasa Resort & Villas Bali, Indonesia.

The primary objective of this book is to provide references for dissemination and discussion of the topics that have been presented in the conference. This volume is unique in that it includes work related to Electrical Engineering, Technology and Information towards their sustainable development. Engineers, researchers as well as lecturers from universities and professionals in industry and government will gain valuable insights into interdisciplinary solutions in the field of Electrical Systems, Technology and Information, and its applications.

The topics of ICESTI 2015 provide a forum for accessing the most up-to-date and authoritative knowledge and the best practices in the field of Electrical Engineering, Technology and Information towards their sustainable development. The editors selected high quality papers from the conference that passed through a minimum of three reviewers, with an acceptance rate of 50.6 %.

In the conference there were three invited papers from keynote speakers, whose papers are also included in this book, entitled: "Computational Intelligence based Regulation of the DC bus in the On-Grid Photovoltaic System", "Virtual Prototyping of a Compliant Spindle for Robotic Deburring" and "A Concept of Multi Rough Sets Defined on Multi-Contextual Information Systems".

The conference also classified the technology innovation topics into five parts: "Technology Innovation in Robotics, Image Recognition and Computational Intelligence Applications", "Technology Innovation in Electrical Engineering, Electric Vehicle and Energy Management", "Technology Innovation in Electronic, Manufacturing, Instrumentation and Material Engineering", "Technology Innovation in Internet of Things and Its Applications" and "Technology Innovation in Information, Modeling and Mobile Applications".

In addition, we are really thankful for the contributions and for the valuable time spent in the review process by our Advisory Boards, Committee Members and Reviewers. Also, we appreciate our collaboration partners (Petra Christian

University, Surabaya; Gunadarma University, Jakarta; UBAYA, Surabaya, University of Ciputra, Surabaya, Institute of National Technology, Malang and LNEE Springer, Germany), our supporting institution (Oulu University, Finland, Widya Mandala Catholic University, Surabaya and Dongseo University, Korea) and our sponsors (Continuing Education Centre, Petra Christian University, Surabaya and Patrajasa Resort Hotel, Bali).

On behalf of the editors Felix Pasila

Chapter 8
Altitude Lock Capability Benchmarking: Type 2 Fuzzy, Type 1 Fuzzy, and Fuzzy-PID with Extreme Altitude Change as a Disturbance

Hendi Wicaksono, Yohanes Gunawan, Cornelius Kristanto and Leonardie Haryanto

Abstract In the past three years, our research developed a low cost QuadRotor. QuadRotor are built from four brushless motors with four Electronic Speed Controllers (ESC) and four propellers in one carbon frame of QuadRotor. KK2 board is added as a flight controller of QuadRotor. This KK2 board has been completed only to deal with altitude stabilization. Our research focused on altitude locking development using several control methods implemented on YoHe board. This paper presents altitude lock capability, to be benchmark between Type2 Fuzzy controller and Type1 Fuzzy controller, also with Fuzzy-PID. The benchmark focuses on their flight analysis performance with extreme altitude change (50 cm) as a disturbance. From that three control methods that have applied, and overall tested, Type2 Fuzzy shows better result than others.

Keywords Type2 fuzzy · Type1 fuzzy · Fuzzy-PID · Altitude lock

8.1 Introduction

QuadRotor is one of a popular Unmanned Aerial Vehicle (UAV). QuadRotor have four rotors to spin symmetrically. This fast growing QuadRotor had been become a popular research's object more than any other UAVs. Many controllers was develop to complete a Quadrotor maneuver. Type2 Fuzzy with Fast Geometric Defuzzification was introduced by Simon [2]. This method shows very important concept to make us able to apply it in the Type2 Fuzzy in a real time. Type1 Fuzzy

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F. Pasila et al. (eds.), *Proceedings of Second International Conference on Electrical Systems, Technology and Information 2015 (ICESTI 2015)*,
Lecture Notes in Electrical Engineering 365, DOI 10.1007/978-981-287-988-2_8

which can be called as Ordinary Fuzzy is a Fuzzy method which was introduced by Zadeh 1965. The comparison of those Fuzzy's structure was well descripted in [1]. PID Controller was used decades years ago, and now days many researchers combine PID Controller with auto tuning from as an output of Fuzzy. It is called a Fuzzy-PID which was explained in [4] and also [3]. Type2 Fuzzy, Type1 Fuzzy, and Fuzzy-PID was designed in our research and have been published. In the past publication, we analyzed the performance of each control method to lock an altitude of QuadRotor. The best control method seen from error percentage is Type2 Fuzzy Control.

The body of this paper is organized as follow. Section 8.2 explains QuadRotor specification which is used in this paper. The control method designs of Type2 Fuzzy, Type1 Fuzzy, and also Fuzzy-PID will be described in Sect. 8.3. The experiment results are given in Sect. 8.4, and finally a conclusion is given in Sect. 8.5.

8.2 QuadRotor Specification and Design

The QuadRotor used in this research was built from scratch. There are eight main parts that should be combined piece by piece to build a one QuadRotor. First, Whirlwind FY450 as a frame was chosen. This frame is made from plastic with several thicknesses so it is strong enough to make it flies. For the motor, four Brushless Motors DC (BLDC) Sunny Sky X2212 which has 980 kV are used. DJI 10 × 4.7 is a propeller installed on BLDC motors. Four DJI 10 × 4.7 with two types direction are installed on the four BLDC motors. As a driver, ZTW Spider 30 A Electronic Speed Controller (ESC) with Pulse Width Modulation (PWM) as an output, is used QuadRotor is shown in Fig. 8.1 and the detail of the parts are shown in Fig. 8.2.

Fig. 8.1 QuadRotor

Fig. 8.2 QuadRotor parts

All control methods were built and processed from YoHe Board. In this application, YoHe Board's functions are:

1. YoHe Board recognizes the manual or auto conditions from a pulse generated from RX Orange when the toggle button is active in TX Orange.
2. In the manual mode, YoHe Board gets and recognizes the throttle signal and makes a pulse signal with sharp as same as the input throttle signal, then sent it to KK2.0 Board.
3. In the auto mode, YoHe Board will activate a sonar sensor and get the current altitude, after that it will calculate an error signal
4. Continue from number 3, YoHe Board is then running a control method coding, whose output is throttle value. After that as it was explained in item number 2, YoHe Board will generate a pulse signal as big as the throttle value and then sent it to KK2.0 Board.

The block connecting all of parts of QuadRotor in general use compare with block connection for altitude lock system with YoHe Board shown in Figs. 8.3 and 8.4. We put in a YoHe Board connection between RX and KK2.0 board. Beside that the system completed with Bluetooth V3 as a media to transfer a data flight from QuadRotor to ground station (laptop).

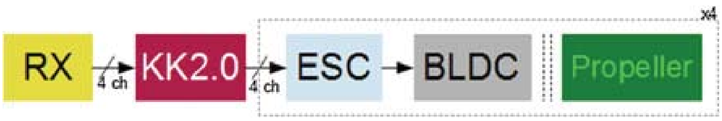

Fig. 8.3 Block connection parts of QuadRotor in general use

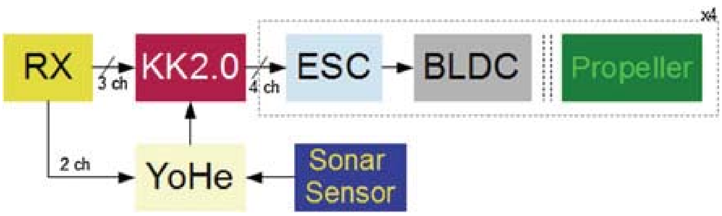

Fig. 8.4 Block connection parts of QuadRotor for altitude lock system

8.3 Control Method Design

In this paper, there are three control methods to compare the altitude lock capability to handle the extreme altitude change disturbance. There are Type2 Fuzzy, Type1 Fuzzy, and Fuzzy-PID. Each control method was published in several publications for their performance analysis. In it's common structure, the design of Type2 Fuzzy and Type1 Fuzzy are quietly similar.

Structure of Type2 Fuzzy is shown in Fig. 8.7, while Fig. 8.8 shows structure of Type1 Fuzzy. The difference between both structures lay at the end of the process. Type2 Fuzzy have Type Reducer step before defuzzyfier step. In this paper, we don't apply a general form of Type2 Fuzzy because it is too hard to make a microcontroller code running at a real time. For that reason, Fast Geometric Defuzzification used in a real time running. We have been trying to make coding with a selection mode to change from one control method to another control method. Because of that mission, YoHe Board completed with ATMega 2560 with 256 KB memory. After Type2 was coded into the board, we decided not to put in all code to the microcontroller because the only Type2 Fuzzy code was taken around 80 % memory capacity.

Both of Type2 Fuzzy and Type1 Fuzzy have a same control process like is shown in Fig. 8.5. In this system have a value defined to height desired and the height (n) getting from sonar sensor measurement. Both of Fuzzy have two inputs, they are an error which calculates from the difference between the desired height and height (n) and a second input is a delta error which calculates from the difference between an error (n) and an error (n – 1). As an output is the throttle value which will be converted to pulse and sent to KK2.0 board. And whereas Fuzzy-PID control process shown in Fig. 8.6. In that figure we can see that an output of Fuzzy

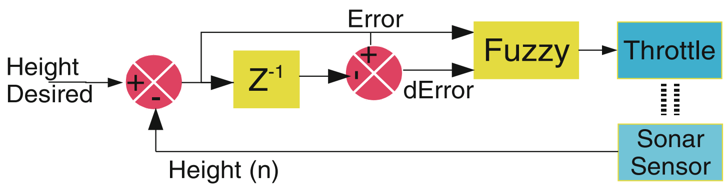

Fig. 8.5 Fuzzy control process

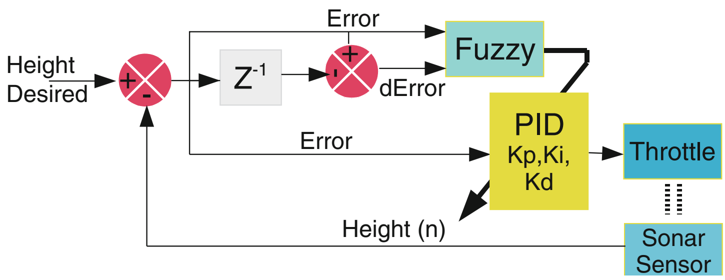

Fig. 8.6 Fuzzy-PID control process

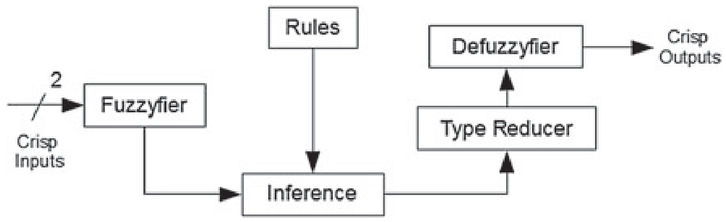

Fig. 8.7 Type2 fuzzy structure

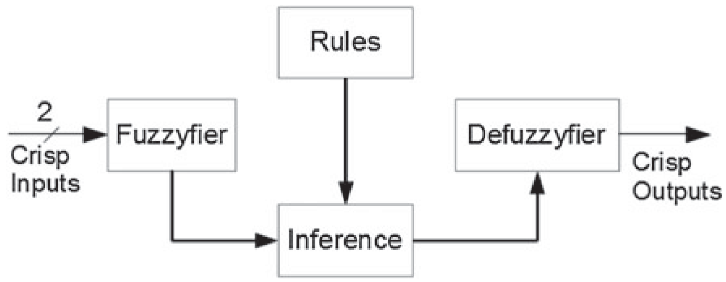

Fig. 8.8 Type1 fuzzy structure

form is a Proportional, Derivative, and Integral constant which will be used by a PID controller.

The structure of Type2 Fuzzy compares to Type1 Fuzzy shown Figs. 8.7 and 8.8. The difference between Type2 Fuzzy Structure and Type1 Fuzzy lies on almost the end of the block. In Type2 Fuzzy there is a type reducer block, which change from Type2 Fuzzy 3 dimensional back to Type1 Fuzzy 2 dimensional so the output can become crisp output. Type2 Fuzzy in general form very difficult to running at a real time. So, Fast Geometric Defuzzification used in this paper. The theory and the calculations of crisp input until became to an output explained more detail in other our publications [5, 6, 7, 8].

8.4 Experiments Results and Discussions

In the experiments, we got flight data through Bluetooth that sent data to our laptop in ground station. We had 1 experiment with five times of flight to get validate data. In this paper, we only gave just one flight data from five data that we had. To simulate an extreme altitude change as a disturbance, our pilot make a + pitch and – pitch maneuver which in the middle there is a box with 50 cm height. The results can be shown in Fig. 8.9.

The disturbance is shown as a red circle. After the extreme altitude change, around 50 cm, we tested how the control method will draw back to the desired height. Because in the real applications it can be happened suddenly. For the quick response after getting a disturbance Type1 Fuzzy and follow with Fuzzy-PID

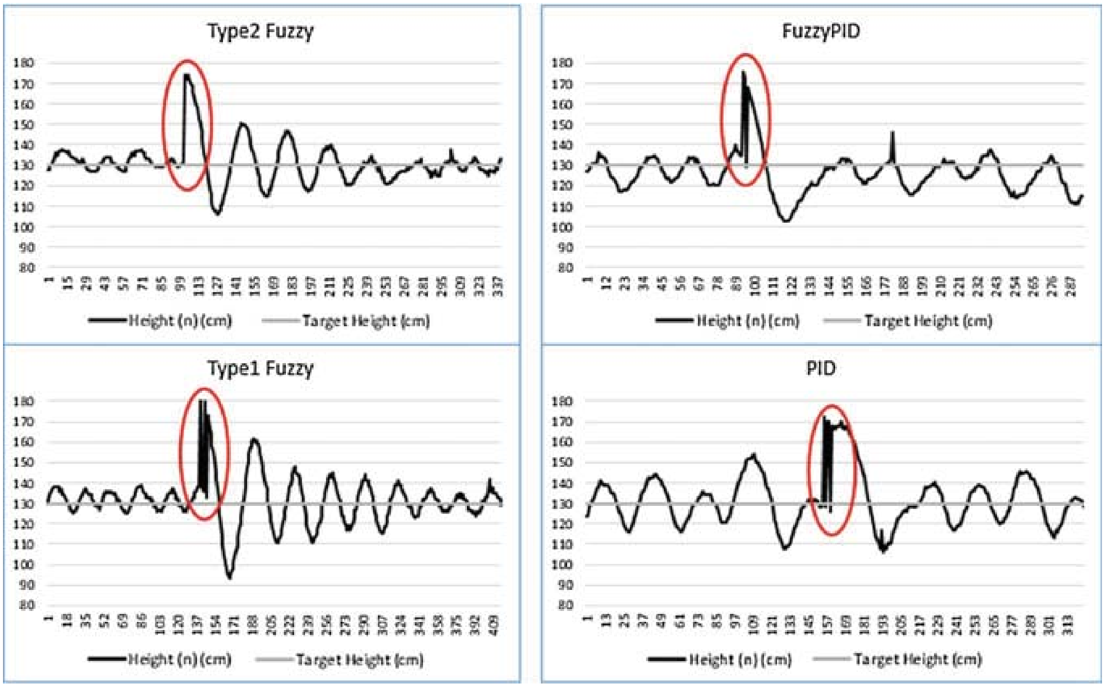

Fig. 8.9 Experiments results

showed a better performance than the Type2 Fuzzy. But, for that quick response, both controllers suffered with bigger oscillations before it came back to it's desired height. They also took longer time than the Type2 Fuzzy. In overall, Type2 Fuzzy is better than the others. Thus this experiment is actually strongly confirmed the other research about Type2 Fuzzy controller which can solve high order non-linearity systems.

8.5 Conclusion

This paper describes a benchmarking between three control methods are Type2 Fuzzy, Type1 Fuzzy, and Fuzzy-PID. There are two important parameters in this benchmarking paper, such as the response of QuadRotor to get the height target, and oscillation happened while the QuadRotor maintain their height target. In a fast response to get their height target, a Type1 Fuzzy is the best one, then followed by Fuzzy-PID, and then Type2 Fuzzy. And for the an oscillation while maintain the height target, Type2 Fuzzy is the best one, then Type1 Fuzzy, and the last is Fuzzy-PID. For future works, a still going re-search is using the camera as a height sensor.

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Lecture Notes in Electrical Engineering

COUNTRY	SUBJECT AREA AND CATEGORY	PUBLISHER	H-INDEX
Germany Universities and research institutions in Germany	Engineering Industrial and Manufacturing Engineering	Springer Verlag	33

PUBLICATION TYPE	ISSN	COVERAGE	INFORMATION
Book Series	18761100, 18761119	2007-2021	Homepage How to publish in this journal leopoldo.angrisani@unina.it

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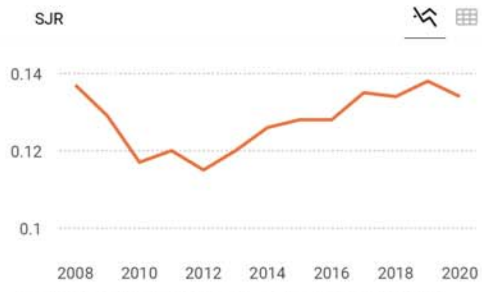

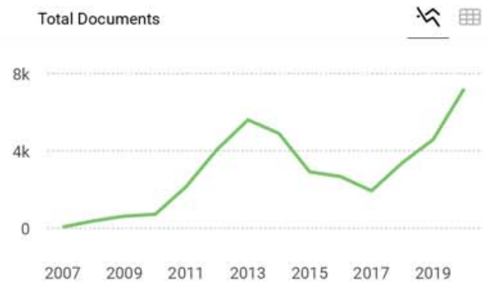

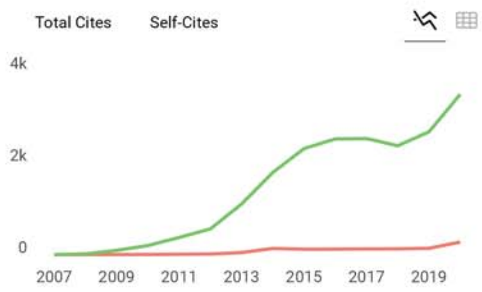

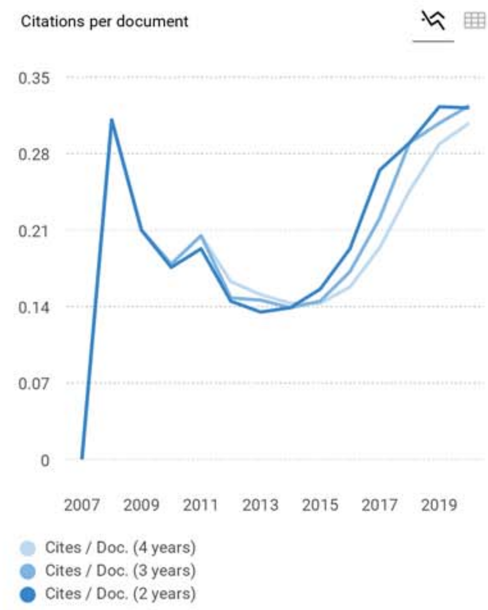

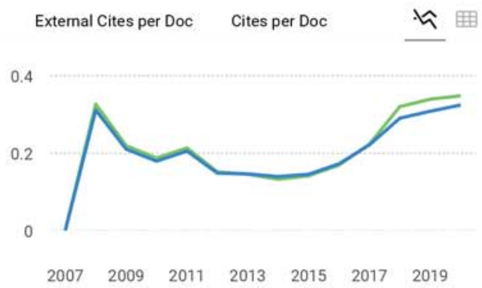

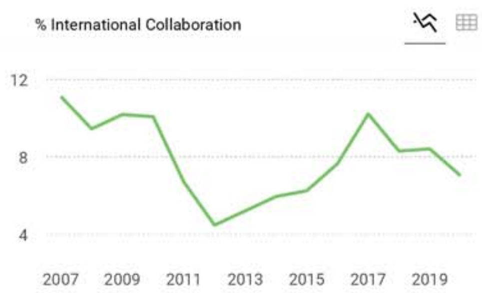

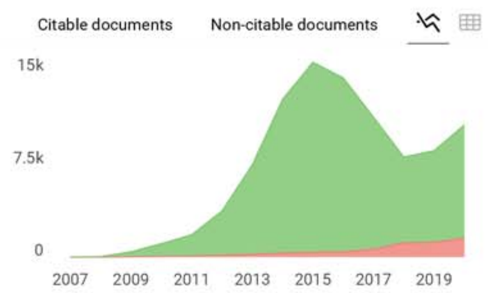

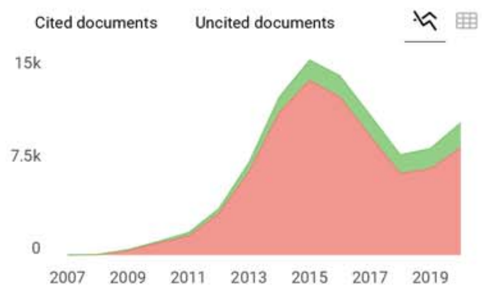

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