



TERAKREDITASI INSTITUSI B  
SK NO. 229/BAN-  
PT/AKRED/PT/IV/2015

# UNIVERSITAS MUHAMMADIYAH SIDOARJO

## DIREKTORAT RISET DAN PENGABDIAN MASYARAKAT

Alamat: Jl. Mojopahit 666 B Sidoarjo 61215, Telp. 031-8945444 psw.130, Faks. 031-8949333

Email: [lppm@umsida.ac.id](mailto:lppm@umsida.ac.id), Website: [lppm.umsida.ac.id](http://lppm.umsida.ac.id)

### Surat Keterangan Tidak Plagiat [Kepangkatan]

Nomor: 522/II.3.AU/14.00/C/KET/I/2022

Kepada Yth :

Bpk. Dr.Izza Anshory, ST., MT.,

Di

Tempat

*Assalamua'alaikum Wr. Wb.*

Sehubungan dengan adanya permohonan Surat Keterangan Tidak Plagiat dengan rincian:

Judul Artikel : Effect of alpha value change on thrust quadcopter Qball-X4 stability testing using backstepping control  
Nama Pemohon : Izza Anshory / Teknik Elektro  
URL Sinta Pemohon : <https://sinta.kemdikbud.go.id/authors/detail?id=5990976&view=overview>  
Nama Penulis : Izza Anshory  
Tujuan : Kepangkatan  
Tujuan Kepangkatan : Lektor

Naskah Yang Dimohonkan pengecekan:

<http://dosen.umsida.ac.id/modul/publikasi/filesktp/19207/sktp-18-01-2022%2009:39:26-19207.pdf>

**Artikel tersebut DAPAT digunakan untuk proses kepangkatan.**

Demikian surat keterangan ini kami sampaikan, mohon untuk digunakan sebagaimana mestinya.

*Wassalamu'alaikum Wr. Wb.*

Mengetahui,  
Wakil Rektor 1  
Universitas Muhammadiyah Sidoarjo

  
Hana Catur Wahyuni, ST., MT

Direktur DRPM

  
Dr. Sigit Hermawan, S.E., M.Si

# sktp-20-01-2022 02\_35\_48- 202239

*by Izza Anshory, St., Mt., Dr.*

---

**Submission date:** 24-Jan-2022 09:03AM (UTC+0700)

**Submission ID:** 1746683558

**File name:** sktp-20-01-2022\_02\_35\_48-202239.pdf (944.64K)

**Word count:** 2651

**Character count:** 11523

PAPER · OPEN ACCESS

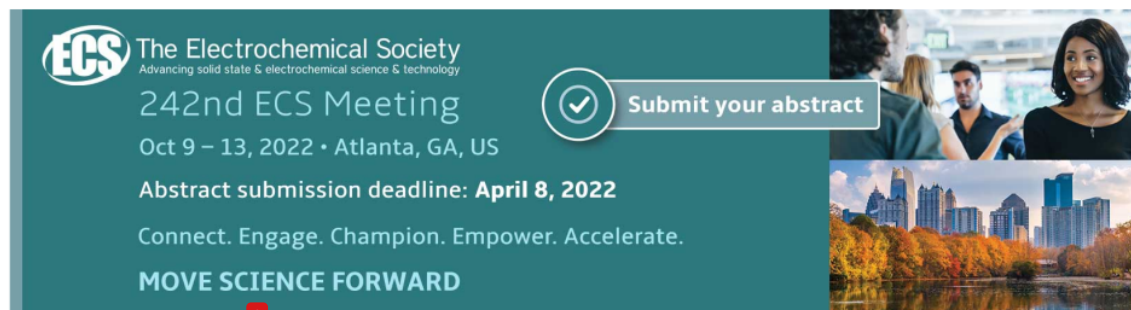
## Effect of alpha value change on thrust quadcopter Qball-X4 stability testing using backstepping control

To cite this article: A T Nugraha *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **434** 012207

View the [article online](#) for updates and enhancements.

### You may also like

- [Research on a Robust Backstepping Attitude Controller for Multi-rotor Plant Protection UAV](#)  
Yunling Liu and Yan Ma
- [PID vs. Backstepping Control for Cooperative Quadrotors Unmanned Aerial Vehicles](#)  
M. Mahfouz, A. Taiomour, Mahmoud M. Ashry et al.
- [Backstepping boundary control: an application to the suppression of flexible beam vibration](#)  
Nipon Boonkumkrong, Pichai Asadamongkon and Sinchai Chinvorarat



**ECS** The Electrochemical Society  
Advancing solid state & electrochemical science & technology

242nd ECS Meeting  
Oct 9 – 13, 2022 • Atlanta, GA, US

Abstract submission deadline: **April 8, 2022**

Connect. Engage. Champion. Empower. Accelerate.

**MOVE SCIENCE FORWARD**

Submit your abstract

The banner features a teal background with white text. On the right side, there are two images: the top one shows a group of people in a professional setting, and the bottom one shows a city skyline with a lake in the foreground.

## Effect of alpha value change on thrust quadcopter Qball-X4 stability testing using backstepping control

A T Nugraha<sup>1,\*</sup>, I Anshory<sup>1</sup> and R Rahim<sup>2</sup>

<sup>1</sup>Electrical Engineering, Universitas Muhammadiyah Sidoarjo, Jl. Mojopahit, Celep, Kec. Sidoarjo, Kabupaten Sidoarjo, Jawa Timur 61271, Indonesia

<sup>2</sup>School of computer and communication engineering, Universiti Malaysia Perlis, Kubang Gajah, Malaysia

\*anggaratnugraha@yahoo.co.id

**Abstract.** Quadrotor or commonly referred to quadcopter or drone, has 4 kinds of movements. One of those movements is the impulse of the movement. In this study, a QBall-X4 quadcopter controller is using a backstepping control system to achieve movement that can reach the height when doing thrust. The results showed that the backstepping method can adjust the height and stabilize the roll angle, pitch and yaw, by adjusting alpha value (a stabilizer constant). The more precisely the alpha value of the system is more stable and the response to reach steady state is faster, with small errors. At setpoint 0 to 3 condition an error of 0.0216.

### 1. Introduction

A quadcopter is an aircraft that has a simple control mechanism that has the potential to take off, hover, fly maneuver, and land even in small and narrow areas [1]. In the use of quadcopter for various purposes, the stability of hover in quadcopter is very important and must be possessed by quadcopter for optimum utilization [2].

In the study of hover stability arrangement on quadcopter using backstepping controls showed good results [3], where the control method was able to control the stability of hover so as to overcome the various disorders given [4]. In the previous study, the backstepping block control method worked well enough when there was no external interference [5], in which the controller was able to control the micro quadcopter motion for a defined waypoint with a small error tracking averages [6]. Therefore to implement it, the quadcopter and actuators are used so that the controller is expected to achieve the stability of the roll and pitch angles and reach the z position height during hover as done during simulation.

### 2. Quadcopter model

Quadcopter Q-ball X4 is an unmanned helicopter combined with four motors whose patterns are crossed [7]. Quadcopter produces lift by the value of all four motors [8].





Figure 1. Quadcopter Qball-X4.

$${}^E_B R = \begin{bmatrix} c\theta c\psi & c\theta c\psi + s\theta s\psi s\phi & s\psi \phi s \\ c\theta s\psi & c\theta s\psi + s\theta c\psi s\phi & s\theta s\psi + s\psi s\theta c\phi \\ s\theta & s\theta s\phi & c\theta c\phi \end{bmatrix} \quad (1)$$

### 2.1. Linearization of quadcopter dynamics models

This section will explain about linearization of dynamics quadcopter [9]. When the quadcopter is in hover condition. The yaw angle is 0 rad and the angular speed of roll, pitch, and yaw are close to 0 rad /s [10].

The state space equation for the linear model of the roll and pitch dynamics can be expressed:

$$\begin{bmatrix} \dot{\phi} \\ \dot{\phi} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{IK_T}{J} \\ 1 & 0 & -\omega \end{bmatrix} \begin{bmatrix} \phi \\ \dot{\phi} \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} = \Delta u_2 \quad (2)$$

$$\begin{bmatrix} \dot{\theta} \\ \dot{\theta} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{IK_T}{J} \\ 1 & 0 & -\omega \end{bmatrix} \begin{bmatrix} \theta \\ \dot{\theta} \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} = \Delta u_1 \quad (3)$$

The linear model of dynamics position which obtained on the axis x and y in the state space is as follows:

$$\begin{bmatrix} \dot{x} \\ \dot{x} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{4K_T}{J} \theta \\ 0 & 0 & -\omega \end{bmatrix} \begin{bmatrix} x \\ \dot{x} \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} u \quad (4)$$

$$\begin{bmatrix} \dot{y} \\ \dot{y} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{4K_T}{J} \psi \\ 0 & 0 & -\omega \end{bmatrix} \begin{bmatrix} y \\ \dot{y} \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} u \quad (5)$$

The value of that parameter is obtained from [11], which written in Table.1 if the v state variable used to present the actuator dynamic.

Table 1. The Parameter value from quadcopter dynamic modelling.

Parameter	Symbol	Value
Mass	$m$	3,499 kg
Gravity	$g$	9,81 kg/m <sup>2</sup>
Inertia Moment on X axis	$J_{xx}$	0.03 kg.m <sup>2</sup>
Inertia Moment on Y axis	$J_{yy}$	0.03 kg.m <sup>2</sup>
Inertia Moment on Z axis	$J_{zz}$	0.04 kg.m <sup>2</sup>

Table 1. Cont.

Distance of rotor from the center of mass	$l$	0.2 m
Drag force	$d$	$3,13 \times 10^{-5}$
Trust Force	$b$	$7,5 \times 10^{-7}$
Actuator Bandwidth	$\omega$	15 rad/s
Constant thrust force	$K$	120 N

### 3. Backstepping controls for altitude edge subsystem [4]

To find the altitude on the quadrotor relate to the axis  $z$ . State  $x_5$  and  $x_6$  which represents the quadrotor altitude of the earth, is taken from the quadrotor model in Equations (4 and 5). The block diagram of the hover height adjustment system on the quadrotor can be seen in Figure 2.

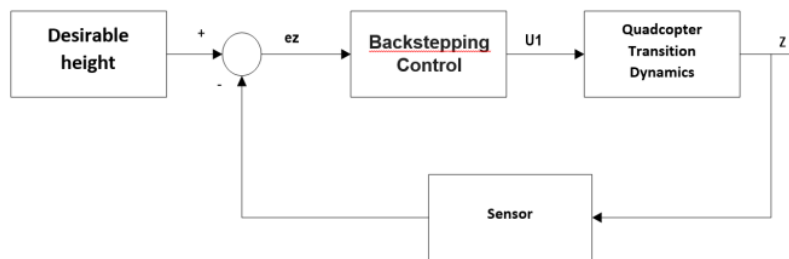


Figure 2. The block diagram of the hover height adjustment system on the quadrotor ( $z$ ).

The last step to look for control signals  $U_1$  for altitude (altitude /  $z$ ) in the same way that is:

#### 3.1. Determine the tracking error to look for errors from altitude ( $z$ )

$$\begin{bmatrix} \dot{y} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{4K_T}{J}\psi \\ 0 & 0 & -\omega \end{bmatrix} \begin{bmatrix} y \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} u \quad (6)$$

$$\begin{bmatrix} \dot{y} \\ \dot{v} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & \frac{4K_T}{J}\psi \\ 0 & 0 & -\omega \end{bmatrix} \begin{bmatrix} y \\ v \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \omega \end{bmatrix} u \quad (7)$$

$$e_7 = z_{ds} - x_5 \quad (8)$$

where  $z_{ds}$  :  $z$  (altitude ref);  $x_5$  :  $z$  (altitude/  $z$ )

#### 3.1.1. Using Lyapunov function to test which stability $V(e_7)$ is definite and positive $-V(e_7)$ is definite negative

$$V(e_7) = \frac{1}{2} e_7^2 \quad (9)$$

$$\dot{V}(e_7) = \frac{1}{2} e_7 \dot{e}_7 \quad (10)$$

$$\dot{V}(e_7) = \frac{1}{2} e_7 (\dot{z}_{ds} - \dot{e}_5) \quad (11)$$

$$\dot{V}(e_7) = e_7 (\dot{z}_{ds} - x_7) \quad (12)$$

To obtain  $e_7$  which is stable then inserted a virtual input control with  $a_7 > 0$

$$x_6 = \dot{z}_{ds} + a_7 e_7 \quad (13)$$

From Eq. (12) is obtained

$$\dot{V}(x_6) = e_7 (\dot{z}_{ds} - x_6) \quad (14)$$

$$\dot{V}(e_7) = e_7 (\dot{z}_{ds} - (x_6 + a_7 e_7)) = -a_7 e_7^2 \quad (15)$$

$$\dot{V} < 0 \quad (16)$$

Next to get  $e_8$ , by changing the variable

$$e_8 = x_6 - \dot{Z}_{ds} - a_7 e_7 \quad (17)$$

### 3.1.2. Lyapunov function augmented

$$V(e_7 e_8) = \frac{1}{2}(e_7^2 + e_8^2) \quad (18)$$

$$\dot{V}(e_7 e_8) = e_7 \dot{e}_7 + e_8 \dot{e}_8 \quad (19)$$

So in can signal overall control as follows:

$$U_2(\text{roll}) = \frac{1}{b_1}(e_7 - a_1 x_{10} x_{12} - a_1 x_{10} \Omega - a_1(e_2 + a_1 e_1) - a_2 e_2) \quad (20)$$

$$U_3(\text{pitch}) = \frac{1}{b_2}(e_3 - a_3 x_8 x_{12} - a_4 x_8 \Omega - a_3(e_4 + a_3 e_3) - a_4 e_4) \quad (21)$$

$$U_4(\text{yaw}) = \frac{1}{b_3}(e_3 - a_3 x_8 x_{10} - a_3(e_6 + a_3 e_3) - a_6 e_6) \quad (22)$$

## 4. Simulation results

### 4.1. Open loop quadcopter testing

In quadcopter can occur thrust when the quadcopter is visually flying float and silent not attached ground or upward force that experienced quarotor equal to gravity. Figure 3 shows the nominal moment or rotational speed equal to zero.

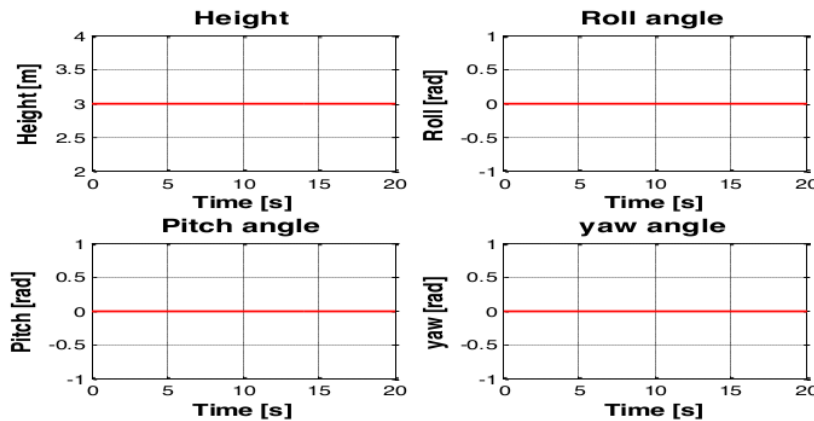


Figure 3. Response elevation (z), rolling angle, pitch and yaw.

The simulation test of open loop quadcopter system shown in Figure 4 with a pulse with mathematical equation at  $z = 0.3\text{m}$  (10%) at 10 seconds, roll angle =  $0.1 \text{ rad / s}$  at 12 seconds, pitch angle =  $0.0001 \text{ rad / s}$  at the 14th second, and the yaw =  $0.1 \text{ rad / s}$  angle at the 16th second indicates that the system is not capable of overcoming the noise that can be seen in the response graph where the height value (z) begins to fall at the 12th second which is about 0.6 m. Time value constant  $\tau = 1.55$  seconds and settling time 6.2 seconds.

Further testing of the same open loop quadrotor system is shown in Figure 5 with a disruption at  $z = 0.6 \text{ m}$  (20%) at 10 seconds, roll angle =  $0.2 \text{ rad / s}$  at 12 seconds, pitch angle =  $0.2 \text{ rad / s}$  at seconds 14, and the yaw =  $0.2 \text{ rad / s}$  angle at the 16th second indicates that the system is not capable of overcoming the disturbance which can be seen in the response graph where the height value (z) drops at 12 seconds by 2.2 m. Value  $\tau = 1.55$  seconds and settling time 6.2 seconds.

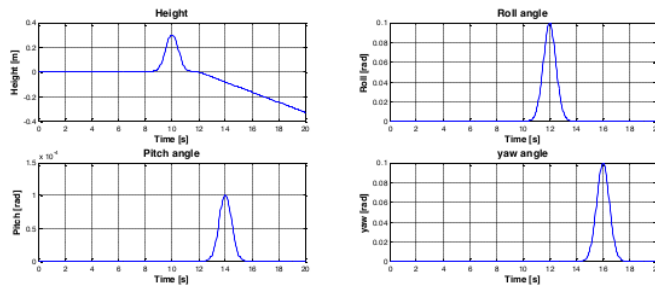


Figure 4. Elevation response (z), rolling angle, pitch, and yaw open loop.

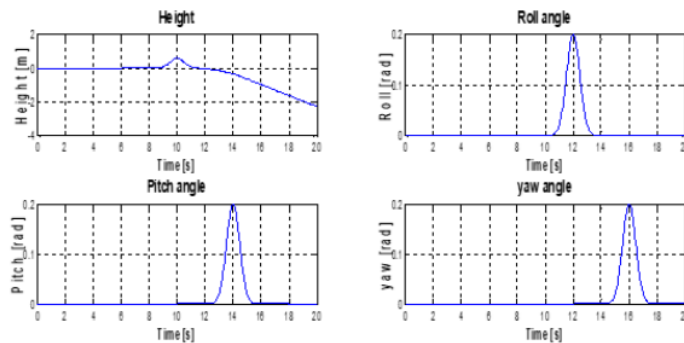


Figure 5. Elevation response (z), rolling angle, pitch, and yaw on open loop.

#### 4.2. Change alpha when testing quadcopter using backstepping control

The effect of alpha on the height response (z) can be seen in Table 2. The greater the alpha value of the system is getting stable and the  $\alpha_7$  is most affected in the settings.

In the backstepping control there is a positive (positive) definite ( $\alpha$ ) function of the stabilizer or its value must be greater than zero, in this study there are 8 alpha  $\alpha_1$  and  $\alpha_2$  to adjust the angle of roll,  $\alpha_3$  and  $\alpha_4$  to adjust the pitch angle,  $\alpha_5$  and  $\alpha_6$  to adjust the angle yaw, and  $\alpha_7$  and  $\alpha_8$  to set the height (z). From the table above can be seen the higher the alpha value of the system is getting stable and the time value constant ( $\tau$ ) is getting smaller. From the above data when  $\alpha = 10$  value  $\tau = 0.6$  seconds,  $\alpha = 200$  value  $\tau = 0.5$  seconds, and  $\alpha = 315$  value  $\tau = 0.4791$  seconds

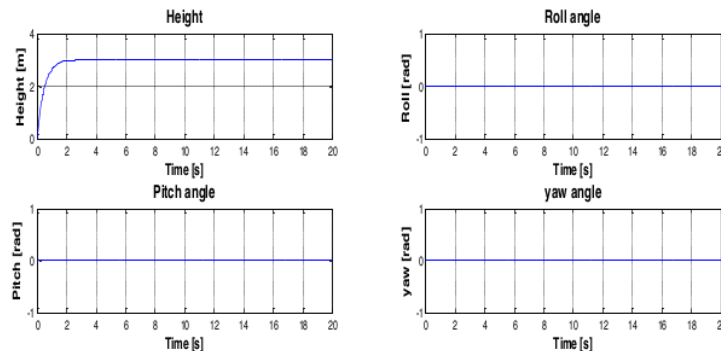


Figure 6. Elevation response, rolling angle, pitch, and yaw.



**Table 2.** Effect of alpha value change on thrust.

No	$\alpha_1$	$\alpha_2$	$\alpha_3$	$\alpha_4$	$\alpha_5$	$\alpha_6$	$\alpha_7$	$\alpha_8$	z	Response
1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	124.18	Unstable
2	1	1	0.9999	0.9999	1	1	1	1	7.908	Overshoot
3	10	1	0.9999	0.9999	1	1	1	1	7.908	Overshoot
4	10	1	0.9999	0.9999	1	1	1	1	7.908	Overshoot
5	10	1	0.9999	0.9999	10	1	1	1	7.908	Overshoot
6	200	1	0.9999	0.9999	200	1	315	1	3.0156	Stable
7	200	1	0.9999	0.9999	200	1	315	1	3.0156	Stable
8	200	1	0.9999	0.9999	200	1	300	1	3.0164	Stable
9	200	1	0.9999	0.9999	200	1	310	1	3.0158	Stable
10	10	1	0.9999	0.9999	10	1	10	1	3.491	A little overshoot
11	100	1	0.9999	0.9999	10	1	10	1	3.491	A little overshoot
12	100	1	0.9999	0.9999	100	1	10	1	3.491	A little overshoot
13	100	1	0.9999	0.9999	100	1	100	1	3.491	A little overshoot
14	100	1	0.9999	0.9999	100	1	200	1	3.0245	somewhat stable
15	200	1	0.9999	0.9999	200	1	200	1	3.0245	somewhat stable

## 5. Conclusions

The simulation result shows that setting using backstepping with proper alpha value determines the stability of roll angle ( $\phi$ ), pitch ( $\theta$ ), yaw ( $\psi$ ) close to zero and to set the height (z) so that the error is very small that is 0.0156 m. The greater the alpha value, the quicker the response to achieve steady state conditions. However, because the error is always fixed or constant for setpoint zero up to 3 then added the offset value on the setpoint so that the error becomes zero. The time value is constant to fly thrust 0.4791 seconds.

## References

- [1] Salvador G-V and Javier M-V 2011 "A new nonlinear PI/PID controller for Quadcopter posture regulation," *2010 Electronics, Robotics and Automotive Mechanics Conference*.
- [2] Rabhi A, Chadli M and Pegard C 2011 "Robust Fuzzy Control for Stableization of a Quadcopter," *The 15th International Conference on Advanced Robotics Tallinn University of Technology Tallinn, Estonia, June 20-23*.
- [3] Bouabdallah S and Siegwart R 2005 "Backstepping and sliding-mode techniques applied to an indoor micro quadcopter," in *Proc. (IEEE) International Conference on Robotics and Automation (ICRA'05), Barcelona, Spain*.
- [4] Bresciani T 2008 *Modelling, Identification and Control of a Quadcopter Helicopter* (Department of Automatic Control Lund University).
- [5] Boyd S, El Ghaoui L, Feron E and Balakrishnan V 1994 *Linear Matrix Inequalities in System and Control Theory* (Philadelphia: Society for Industrial and Applied Mathematics).
- [6] "Unmanned Flight" 2014 *IEEE Control System Magazine* 34 (1).
- [7] Antonio Tsourdos, Brian A W and Madhavan S 2011 *Cooperative path planning of Unmanned Aerial Vehicles* (John Wiley & Sons, Ltd).
- [8] Quanser Q-Ball X-4 User Manual, Quanser Innovate Educate, 2010, Doc. 888 Rev.2 pp. i-46.
- [9] de Almeida Neto M M 2014 *Control strategies of a tilt-rotor UAV for load transportation* (Master Thesis, Universidade Federal de Minas Gerais).
- [10] Frank L Lewis, Stevens B L and Eric N Johnson 2016 *Aircraft Control and Simulation – 3rd ed*

- (John Wiley & Sons, Inc., Canada).  
[11] Thor I Fossen 2011 *Handbook of Marine Craft Hydrodynamics and Motion Control* (John Wiley & Sons, Inc., Canada).

ORIGINALITY REPORT

---

7%

SIMILARITY INDEX

9%

INTERNET SOURCES

6%

PUBLICATIONS

5%

STUDENT PAPERS

---

PRIMARY SOURCES

---

1 N Rochmah, U Cahyana, A Purwanto. "Development of mobile learning: Basis of ethnopedagogy of Baduy Community, Banten Province", IOP Conference Series: Materials Science and Engineering, 2021 4%  
Publication

---

2 [umpir.ump.edu.my](http://umpir.ump.edu.my) 2%  
Internet Source

---

3 [www.scribd.com](http://www.scribd.com) 2%  
Internet Source

---

Exclude quotes On

Exclude matches < 2%

Exclude bibliography On