



# PROCEEDINGS

2021 8<sup>th</sup> International Conference  
on Electrical Engineering, Computer Science  
and Informatics

October 20-21, 2021  
Semarang - Indonesia

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## PROCEEDINGS

**8<sup>th</sup> International Conference on Electrical Engineering,  
Computer Science and Informatics (EECSI) 2021**

October 20-21, 2021  
Semarang – Indonesia  
(Virtual Conference)

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M Amjad (Islamia University of Bahawalpur, Pakistan)  
Imam MI Subroto (UNISSULA, Indonesia)  
Mochammad Facta (Universitas Diponegoro, Indonesia)

## PROCEEDINGS

### 8<sup>th</sup> International Conference on Electrical Engineering, Computer Science and Informatics (EECSI) 2021



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## **Opening Speech - EECSI 2021**

***Assalamu'alaikum Warrohmatullohi Wabarakatuh.***

In the name of Allah, the Most Beneficent, the Most Merciful.

Praise and gratitude to Allah, God Almighty who keeps granting us His grace, gifts and guidance, as well as the implementation of the 8<sup>th</sup> International Conference on Electrical Engineering, Computer Science and Informatics 2021 (EECSI 2021) hosted by Universitas Islam Sultan Agung (UNISSULA) Semarang, Indonesia. The conference theme this year is interesting; "**Bridge Toward Industrial Revolution 4.0 and Its Applications on Electrical, Electronics, Computer Science and Informatics for Humanity**". The event is intended to provide technical forum and research discussion related to advanced engineering on electrical & electronics, computer science and informatics. The conference is aimed to bring researchers, academicians, scientists, students, engineers and practitioners together to participate and present their latest research findings, developments and applications related to the various aspects of electrical, electronics, power electronics, instrumentation, control, robotics, computer & telecommunication engineering, signal, image & video processing, soft computing, computer science and informatics.

Hereby, I would like to congratulate the Industrial Technology Faculty, Universitas Islam Sultan Agung Semarang for their effort in organizing the 2021 8<sup>th</sup> International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2021). My highest appreciation is also addressed to all co-organizers such as Universitas Diponegoro, Universitas Ahmad Dahlan, Universitas Sriwijaya, Universitas Budi Luhur, and Universiti Teknologi Malaysia for their support in this mutual collaboration. Without the full and valuable supports from the international committee, international reviewers, and steering committee, this international conference remains a detached discourse without high commitment to conduct.

My deepest gratitude is also devoted to IEEE Indonesia Section and IAES Indonesia Section for their support as the sponsors and technical co-sponsorship, respectively. Expectantly, this would be the initial and continual collaboration in the future.

To all speakers, presenters, and participants, thank you for participating and welcome to this conference. The success of this conference owes so much on your participation and contribution in promoting the knowledge, information, and robust creativity. To end with, this conference expectedly becomes an arena to build mutual ties among the academicians, researchers, industries, and society.

All the best to EECSI 2021

***Wassalamu'alaikum Warrohmatullohi Wabarakatuh.***

**Drs. H. Bejo Santoso, M.T., Ph.D**

Rector

Universitas Islam Sultan Agung (UNISSULA)  
Semarang, Indonesia

## **Foreword from General Chair EECSI 2021**

In the name of Allah, Most Gracious, Most Merciful

Welcome to the 8<sup>th</sup> International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2021). The 8th EECSI 2021 provides platform for researchers, academicians, professionals, and students from various engineering fields and with cross-disciplinary working or interested in the field of Electrical Engineering, Computer Science, and Informatics to share and to show their works and findings to the world.

This year, the conference is held virtually, due to the pandemic issue which prevent authors and participants to travel. I would like to express my hearty gratitude to all participants for sharing and presenting your experiences in this virtual conference. Only high-quality selected papers are accepted to be presented in this event, so we are also thankful to all the international reviewers and steering committee for their valuable work. I would like to give a compliment to all partners in publications and sponsorships for their valuable supports.

Organizing such an prestigious conference was incredibly challenging and would have been impossible without our outstanding committee, so I would like to extend my sincere appreciation to all committees and volunteers from Universitas Islam Sultan Agung (UNISSULA) as a host and all colleagues from Universitas Diponegoro, Universitas Sriwijaya, Universitas Ahmad Dahlan, Universitas Muhammadiyah Malang, Universitas Budi Luhur and IAES Indonesia Section for providing me with much needed support, advice, and assistance on all aspects of the conference. A special thanks for IEEE Indonesia Section for the technical co-sponsorship during the conference. We do hope that this event will encourage the collaboration among us now and in the future.

We wish you all find opportunity to get rewarding technical program, intellectual inspiration and forge innovation. Stay at home, stay safe, and be productive.

Arief Marwanto, Ph.D  
General Chair, EECSI 2021



## **Foreword from IAES Indonesia Section**

Bismillahirrohmarrahim,  
Assalamualaykum warohmatullahi wabarakatuh and Good Day,  
Ladies and Gentlemen,

We would like to welcome our colleagues to attend the International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2021) on 20-21 October 2020.

I hope this event will become a great event for researchers, engineers and professionals to strengthen ties and partnerships and their findings and development to the world in the field of electrical, computer, and informatics. This year, the conference is held virtually using Zoom Conference platform, however, I believe the quality of conference can be maintained in the high level.

Institute Advanced Engineering and Science (IAES) collaborating with Universitas Diponegoro, Universitas Islam Sultan Agung, Universitas Sriwijaya, Universitas Budi Luhur and Universiti Teknologi Malaysia as several tops universities have successfully organized the conference six times since year 2014. This achievement is due to valuable contributions also from our colleagues from Universitas Islam Sultan Agung (UNISSULA). I would like to express my sincere gratitude and appreciation for all partners, friends, organizing committee, reviewers, keynote speakers, and participants who have made this event as a key stage to show great development to the world as today.

I would also like to extend my gratitude to Rector of Universitas Islam Sultan Agung (UNISSULA), academia and supporting staffs who become a main host and IEEE Indonesia section as a technical co-sponsor for EECSI 2021.

Stay safe, and stay strong.

Thank you.

Assoc.Prof. Mochammad Facta, Ph.D  
IAES – Indonesia Chapter

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## **2021 8th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI) Program**

**Wednesday, October 20 8:30 - 11:30**

### **INV: Invited Paper**

#### **8:30 90-100GHz Radar for High Precision Foreign Object Debris Detection System: Experience Sharing from Research to Airport Operation**

[Sevia Mahdaliza Idrus Sutan Nameh](#) (Universiti Teknologi Malaysia, Malaysia)

#### **9:30 Automated feature extraction in deep learning models: A boon or a bane?**

[D. Jude Hemanth](#) (Karunya Institute of Technology and Sciences, India)

#### **10:30 Embedded Machine Learning for the implementation of Autonomous Mobile Sensor Nodes (AMSNs)**

[Luca Di Nunzio](#) (University of Rome "Tor Vergata", Italy)

**Wednesday, October 20 12:30 - 14:30**

### **R1-1: Parallel Room 1**

#### **R1-1.1 12:30 Enhancing LLWAS to Predict LLWS Phenomenon Using Temporal Convolutional Network**

[Muhammad Ryan](#) (University of Indonesia, Indonesia); [Adhi Harmoko Saputro](#) (Universitas Indonesia, Indonesia); [Ardhasena Sopaheluwakan](#) (Indonesian Agency For Meteorology, Climatology, And Geophysics, Indonesia)

#### **R1-1.2 12:45 BSEVOTING: A Conceptual Framework to Develop Electronic Voting System using Sidechain**

[Syada Tasmia Alvi](#) (Daffodil International University, Bangladesh); [Linta Islam](#) (Jagannath University, Bangladesh); [Tamanna Rashme](#) (Uttara University, Bangladesh); [Mohammed Nasir Uddin](#) (Jagannath University, Bangladesh)

#### **R1-1.3 13:00 Overview of WBAN from Literature Survey to Application Implementation**

[Israa Al Barazanchi](#) (College of Computing and Informatics & Universiti Tenaga Nasional (UNITEN), Malaysia); [Wahidah Hashim](#) (Universiti Tenaga Nasional, Malaysia); [Haider Hadi Abbas](#) (Al-Mansour University College, Iraq); [Ammar Alkahtani](#) (Universiti Tenaga Nasional & UNITEN, Malaysia); [Haider Abdulshaheed](#) (Baghdad College, Iraq)

#### **R1-1.4 13:15 Experimental Analysis of IPv6 Tunneling of Jumbo Frame Transmission using Mikrotik Routers**

[Arief Marwanto](#) (Universitas Islam Sultan Agung (UNISSULA) Semarang, Indonesia); [Imam Much Ibnu Subroto](#) and [Yahya Hidayatullah](#) (Universitas Islam Sultan Agung, Indonesia)

#### **R1-1.5 13:30 A Dimensionality Reduction Approach for Machine Learning Based IoT Botnet Detection**

[Susanto Susanto](#) (Sriwijaya University & Universitas Bina Insan, Indonesia); [Deris Stiawan](#) (University of Sriwijaya, Indonesia); [M. Agus Syamsul Arifin](#) (Universitas Sriwijaya & Universitas Bina Insan, Indonesia); [Juli Rejito](#) (Universitas Padjadjaran, Indonesia); [Mohd. Yazid Idris](#) (Universiti Teknologi Malaysia, Malaysia); [Rahmat Budiarto](#) (Al Baha University, Saudi Arabia)

#### **R1-1.6 13:45 Complaint Data Text Analysis Concerning the Apps provided by Government Agency using Inference LDA**

[Adhi Dharma Wibawa](#) and [Rizky Eka Listanto](#) (Institut Teknologi Sepuluh Nopember, Indonesia)

#### **R1-1.7 14:00 Optimization of Multi-Controller Locations in SDWAN using Various Method**

[Victor Lamboy Sinaga](#) and [Riri Fitri Sari](#) (University of Indonesia, Indonesia)

#### **R1-1.8 14:15 n-gram Effect in Malware Detection Using Multilayer Perceptron (MLP)**

[Benni Purnama](#) (Universitas Dinamika Bangsa Jambi, Indonesia); [Deris Stiawan](#) (University of Sriwijaya, Indonesia); [Darmawijoyo Hanapi](#) (Sriwijaya University, Indonesia); [Eko Arip Winanto](#) (Universiti Teknologi Malaysia, Malaysia); [Rahmat Budiarto](#) (Al Baha University, Saudi Arabia); [Mohd. Yazid Idris](#) (Universiti Teknologi Malaysia, Malaysia)

**R2-1: Parallel Room 2**

**R2-1.1 12:30 Smart Loading Management System for Hybrid Photovoltaic/Wind Power Supply**

Syafii Syafii, Darwison Darwison and Muhardika Muhardika (Universitas Andalas, Indonesia); Witi Onanda (Padang State Polytechnic, Indonesia)

**R2-1.2 12:45 Spiral-Coupled-Line Resonators for Chipless RFID Sensors**

Wazie M. Abdulkawi (Riyadh - KSA, Saudi Arabia & King Saud University, Saudi Arabia); Abdel Fattah Sheta (King Saud University, College of Engineering, Saudi Arabia); Ibrahim Elshafiey and Majeed Alkanhal (King Saud University, Saudi Arabia)

**R2-1.3 13:00 Load Effect on Switched Reluctance Motor Using Hysteresis Current and Voltage Control**

Agus Adhi Nugroho (Universitas Islam Sultan Agung (UNISSULA), Indonesia); Muhammad Khosyi'in and Bustanul Arifin (Universitas Sriwijaya & Universitas Islam Sultan Agung, Indonesia); Muhamad Haddin (Universitas Islam Sultan Agung, Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia); Zainuddin Nawawi (Universitas Sriwijaya, Indonesia)

**R2-1.4 13:15 Fuzzy Logic Controller Application to an Automatic Corn Sheller**

Hendra Marta Yudha (Universitas Tridinanti Palembang, Indonesia); Tresna Dewi (Politeknik Negeri Sriwijaya, Indonesia); Pola Risma (Sriwijaya Polytechnic, Indonesia); Yurni Oktarina (Polytechnic Sriwijaya Palembang-Indonesia, Indonesia); Suci Syalifa Zara and Inda Sartika (Politeknik Negeri Sriwijaya, Indonesia)

**R2-1.5 13:30 Development of Heater and Mixer Machine With Control System for Biodiesel Production**

Made Rahmawaty, Hendriko Hendriko and Engla Puspita Haryanisa (Politeknik Caltex Riau, Indonesia)

**R2-1.6 13:45 The AC-DC-AC Converter Design for Parallel Asynchronous Generator Based Microhydro Power Plants**

Arief Marwanto (Universitas Islam Sultan Agung (UNISSULA) Semarang, Indonesia); Muhamad Haddin (Universitas Islam Sultan Agung, Indonesia); Marwan Rosyadi and Rudi Irmawanto (Universitas Muhammadiyah Surabaya, Indonesia)

**R2-1.7 14:00 Leakage Current Monitoring for Electrical Loads Based on Internet of Things**

Riky Tri Yunardi, Erwin Sutanto and Aji Akbar Firdaus (Universitas Airlangga, Indonesia); Elysea Adia Tunggadewi (University of Airlangga, Indonesia)

**R2-1.8 14:15 Embedded Alcohol Sensing Design And Analysis For Air Samples**

Munaf Ismail (Universitas Islam Sultan Agung, Indonesia); Arief Marwanto (Universitas Islam Sultan Agung (UNISSULA) Semarang, Indonesia); Jenny Putri Hapsari (Faculty of Industrial Engineering, Universitas Islam Sultan Agung, Indonesia); Muhamad Haddin (Universitas Islam Sultan Agung, Indonesia)

## R3-1: Parallel Room 3

**R3-1.1 12:30 Determinants of Citizen Adoption to Engage in Instagram for Public Services**

Ahmad Henda Maulana and Putu Wuri Handayani (Universitas Indonesia, Indonesia)

**R3-1.2 12:45 Design Approach in Conference Management System with EZDESK Dashboard for Digital Ecosystem**

Muharman Lubis and Iqbal Zunaedi (Telkom University, Indonesia); Ahmad Musnansyah (Telkom University Bandung, Indonesia); Rahmat Fauzi (Telkom University, Indonesia)

**R3-1.3 13:00 The Effect of E-Commerce Towards Sales Growth on Social Media among Students in Indonesia**

Arif Ridho Lubis and Santi Prayudani (Politeknik Negeri Medan, Indonesia); Muharman Lubis (Telkom University, Indonesia); Al-Khowarizmi Al-Khowarizmi (Universitas Muhammadiyah Sumatera Utara, Indonesia)

**R3-1.4 13:15 Resource Reservation in DetNet with AVB**

Csaba Simon, Miklós Máté and Markosz Maliosz (Budapest University of Technology and Economics, Hungary)

**R3-1.5 13:30 Fuzzy Implementation for Land Spatial Planning**

Andi Riansyah (Universitas Islam Sultan Agung, Indonesia); Rahmat Gernowo (Diponegoro University, Indonesia); Suryono Suryono (Faculty of Science and Mathematics Diponegoro University, Indonesia); Dedy Kurniadi (Universitas Islam Sultan Agung, Indonesia)

**R3-1.6 13:45 Suitability of FPS and DPS in NOMA for Real-Time and Non-Real Time Applications**

Moontasir Rafique, Abdullah Alavi, Aadnan Farhad and Mohammad T. Kawser (Islamic University of Technology, Bangladesh)

**R3-1.7 14:00 Imparting Full-Duplex Wireless Cellular Communication In 5G Network Using Apache Spark Engine**

Zahraa A. Jaaz (Universiti Tenaga Nasional (UNITEN), Malaysia); Intesar Yaseen Khudhair (University of Diyala, Iraq); Hala Mehdy (Universiti Tenaga Nasional (UNITEN), Malaysia); Israa Al Barazanchi (College of Computing and Informatics & Universiti Tenaga Nasional (UNITEN), Malaysia)

**R3-1.8 14:15 Calibration of 93.1GHz FOD Detection Radar on Airport Runway using Trihedral Corner Reflector**

Nur Aqilah Yusri (Universiti Teknologi Malaysia & FRGS, Malaysia); Sevia Mahdaliza Idrus Sutan Nameh (Universiti Teknologi Malaysia, Malaysia); Norliza Mohamed (Universiti Teknologi Malaysia & Razak Faculty of Technology and Informatics, Malaysia); Sumiyati Ambran (Universiti Teknologi Malaysia & Malaysia-Japan International Institute of Technology, Malaysia); Farabi Iqbal (Universiti Teknologi Malaysia, Malaysia); Tetsuya Kawanishi (Waseda University & National Institute of Information and Communications Technology, Japan); Atsushi Kanno (National Institute of Information and Communications Technology, Japan); Nobuhiko Shibagaki (Hitachi Kokusai Electric, Japan); Kenichi Kashima (Hitachi Kokusai Electric Inc., Japan)

## R4-1: Parallel Room 4

### R4-1.1 12:30 *Workspace and Collaboration System Design of Two Robot Manipulators*

Tresna Dewi, Rusdianasari Rusdianasari, Rd. Kusumanto and Siproni Siproni (Politeknik Negeri Sriwijaya, Indonesia)

### R4-1.2 12:45 *Position Control System of Autonomous Underwater Vehicle using PID Controller*

Ike Bayusari and Albert Mario Alfarino (Sriwijaya University, Indonesia); Hera Hikmarika (Universitas Sriwijaya, Indonesia); Zaenal Husin (University of Sriwijaya, Indonesia); Suci Dwijayanti (Sriwijaya University, Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia)

### R4-1.3 13:00 *Ultrasonic Multi-Sensor Detection Patterns On Autonomous Vehicles Using Data Stream Method*

Eka Nuryanto Budisusila (Universitas Islam Sultan Agung & Universitas Sriwijaya, Indonesia); Muhammad Khosyi'in (Universitas Sriwijaya & Universitas Islam Sultan Agung, Indonesia); Sri Artini Dwi Prasetyowati (Universitas Islam Sultan Agung, Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia); Zainuddin Nawawi (Universitas Sriwijaya, Indonesia)

### R4-1.4 13:15 *YOLO Algorithm-Based Surrounding Object Identification on Autonomous Electric Vehicle*

Irvine Valiant Fanthony (Sriwijaya University, Indonesia); Zaenal Husin (University of Sriwijaya, Indonesia); Hera Hikmarika (Universitas Sriwijaya, Indonesia); Suci Dwijayanti (Sriwijaya University, Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia)

### R4-1.5 13:30 *Strawberry Fruit Quality Assessment for Harvesting Robot using SSD Convolutional Neural Network*

Muhammad Fauzan Ridho (Universitas Multi Data Palembang (UMDP), Indonesia); Irwan Irwan (Universitas Multi Data Palembang, Indonesia)

### R4-1.6 13:45 *Soil Saturation Level Monitoring in Strawberry Plants for Automatizing Grikulan Watering*

Casi Setianingsih (Telkom University, Indonesia)

### R4-1.7 14:00 *Integration of Color and Shape Features for Household Object Recognition*

Muhammad Attamimi, Djoko Purwanto and Rudy Dikairono (Institut Teknologi Sepuluh Nopember, Indonesia)

### R4-1.8 14:15 *Design of Autonomous Vehicle Navigation Using GNSS Based on Pixhawk 2.1*

Muhammad Khosyi'in (Universitas Sriwijaya & Universitas Islam Sultan Agung, Indonesia); Eka Nuryanto Budisusila (Universitas Islam Sultan Agung & Universitas Sriwijaya, Indonesia); Sri Artini Dwi Prasetyowati (Universitas Islam Sultan Agung, Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia); Zainuddin Nawawi (Universitas Sriwijaya, Indonesia)

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Hanung Adi Nugroho, Eka Legya Frannita and Rizki Nurfauzi (Universitas Gadjah Mada, Indonesia)

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Partho Ghose and Uzzal Kumar Acharjee (Jagannath University, Bangladesh); Md. Amirul Islam (World University of Bangladesh, Bangladesh); Selina Sharmin and Md. Ashraf Uddin (Jagannath University, Dhaka, Bangladesh)

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Widhi Winata Sakti (University Of Jember, Indonesia); Khairul Anam and Satryo Utomo (University of Jember, Indonesia); Bambang Marhaenanto and Safri Nahela (Universitas Jember, Indonesia)

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Yohannes Yohannes, Wijiang Widhiarso and Indra Pratama (Universitas Multi Data Palembang, Indonesia)

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Cut Fiarni (ITHB, Indonesia)

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Surisno Sutrisno (Universitas Diponegoro, Indonesia); Widowati Widowati and Heru Tjahjana (Diponegoro University, Indonesia)

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Muhammad Fachrie and Farida Ardiani (Universitas Teknologi Yogyakarta, Indonesia)

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Wibby Aldryani Astuti Praditasari (Indonesia Defense University & Universitas Pertahanan, Indonesia); Ria Aprilliyani (Indonesia Defense University, Indonesia); Ikhwannul Kholis (Universitas Mpu Tantular, Indonesia)

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Bustanul Arifin (Universitas Sriwijaya & Universitas Islam Sultan Agung, Indonesia); Agus Adhi Nugroho (Universitas Islam Sultan Agung (UNISSULA), Indonesia); Bhakti Yudho Suprapto (University of Sriwijaya, Indonesia); Sri Artini Dwi Prasetyowati (Universitas Islam Sultan Agung, Indonesia); Zainuddin Nawawi (Universitas Sriwijaya, Indonesia)

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Agnes Diza Fahira and Adhi Harmoko Saputro (Universitas Indonesia, Indonesia)

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[Afif Zuhri Arfianto](#) (Shipbuilding Institute of Polytechnic Surabaya (PPNS), Indonesia); [Lilik Subiyanto](#) (Shipbuilding Institute of Polytechnic Surabaya, Indonesia)

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[Idouw Iseoluwa Ajayi](#) (Institut Supérieur d'Electronique de Paris, France); [Yahia Medjahdi](#) (IMT Nord Europe, France); [Lina Mroueh](#) (Institut Supérieur d'Electronique de Paris, France); [Fatima Kaddour](#) (Agence Nationale des Fréquences, France)

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[Markus Hermawan](#) (Sriwijaya University, Indonesia); [Zaenal Husin](#) (University of Sriwijaya, Indonesia); [Hera Hikmarika](#) (Universitas Sriwijaya, Indonesia); [Suci Dwijayanti](#) (Sriwijaya University, Indonesia); [Bhakti Yudho Suprapto](#) (University of Sriwijaya, Indonesia)

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# Position Control System of Autonomous Underwater Vehicle using PID Controller

Ike Bayusari

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
ikebayusari@yahoo.co.id*

Albert Mario Alfarino

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
alfmario104@gmail.com*

Hera Hikmarika

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
herahikmarika@gmail.com*

Zaenal Husin

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
zaenalhusin@gmail.com*

Suci Dwijayanti

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
sucidwijayanti@ft.unsri.ac.id*

Bhakti Yudho Suprapto

*Dept. of Electrical Engineering  
Faculty of Engineering, Universitas  
Sriwijaya  
Palembang, Indonesia  
bhakti@ft.unsri.ac.id*

**Abstract –** Water covers most of the earth's surface compared to the land, including Indonesia. Such an area can be explored using an underwater robot, which is implemented in an autonomous underwater vehicle (AUV). The AUV control system requires a controller to be able to move properly. Thus, a PID controller that has a simple structure and yields great performance can be implemented in the AUV. This study was conducted to control the movement of the surge, heave, and yaw of the AUV using the PID. The AUV modeling simulations were carried out using Simulink to determine the PID gain values. The simulation results for surge movement were  $K_p = 38.41$ ,  $K_i = 10.8$  and  $K_d = 58.4$ , heave movement were  $K_p = 49.13$ ,  $K_i = 2.56$  and  $K_d = 107.12$  and yaw movement were  $K_p = 3.18$ ,  $K_i = 0.18$  and  $K_d = 12.11$ . The results showed that AUV could perform well and maintain the position determined by the set point for 3-4 seconds.

**Keywords:** Autonomous Underwater Vehicle, PID, Control System, Simulink.

## I. INTRODUCTION

Water makes up about 71% of the Earth's surface compared to the land, including in Indonesia. According to the Ministry of Marine Affairs and Fisheries, water covers about 3.25 million Km<sup>2</sup> of Indonesia [1]. Thus, underwater exploration can be carried out by the government or society for various purposes. However, underwater exploration carried out by humans has a high potential for accidents and death because of the quick environment changing.

To overcome it, nowadays, underwater exploration is done by using underwater robots [2][3]. The underwater robot is the right solution to replace humans in doing underwater tasks or missions. The underwater robot can perform simple to difficult tasks, such as underwater research, underwater resource search, underwater pipeline observation, port defense and security, and also application in the military area [4]. The most important thing while using an underwater robot is the control system for controlling the position and movement of the robot. The position control system on the robot is needed to specify the condition and position in the water.

In general, there are two kinds of underwater robots, namely Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicles (AUV). The AUV is an underwater robot that can automatically perform some tasks without an operator. The AUV needs controllers to control its movement. Various studies have been performed to control the AUV, such as Proportional Integral Derivative (PID) controller [5][6], self-adaptive Fuzzy-PID [7], Adaptive control [8],

Neural Network-Fuzzy [2], Particle Swarm Optimization (PSO)-PID with derivative filter [9], and PID based on grey wolf optimizer [10]. Some of these controllers show great results in controlling the AUV, for example [5-10] which did a study about depth control, and [6-8] discussed the AUV simulation control systems.

However, the previous studies only implemented the simulation control system and only controlled the depth. Therefore, this study was conducted in simulation and AUV experimental test on navigation, position, and depth position using PID controller. The PID controller has a simple structure and yields great performance in various systems [6].

This paper is organized as follows, Section 2 describes the autonomous underwater vehicle, kinematic and dynamic equations of the AUV, and PID controller. Then, Section 3 presents the methods used in this work. The results and discussion are shown in Section 4. This work is then concluded in Section 5.

## II. LITERATURE REVIEW

### A. Autonomous Underwater Vehicle

Autonomous Underwater Vehicle (AUV) denotes a vehicle that can move automatically without a human as an operator. It can perform various tasks and missions in place or conditions that are difficult for humans. The AUV is equipped with several sensors as a control system, communication, and collecting data or required information, then proceed them to the operator.

### B. AUV Kinematics

All degrees of freedom on world coordinate system (W) and body coordinate system (B) can be written in vector equation [11] as

$$\begin{aligned} \chi &= [\text{surge } \text{sway } \text{heave } \text{roll } \text{pitch } \text{yaw}]^T \\ &= [x_B \ y_B \ z_B \ \phi_B \ \theta_B \ \Psi_B]^T \end{aligned} \quad (1)$$

$$\eta = [x \ y \ z \ \varphi \ \theta \ \Psi]^T. \quad (2)$$

Equations (1) and (2) can determine the orientation, velocity, acceleration, and navigation of the world and body coordinate system of AUV [11].

Euler angle is used to relate the orientations of both coordinate systems. Euler angle equation can be written as

$$R^{BW}(\varphi, \theta, \Psi) = R_z(\Psi)R_y(\theta)R_x(\varphi). \quad (3)$$

Linear velocity or acceleration of coordinate system W can be calculated using this following equation:

$$J_1(V_W) = R^{BW}(V_W). \quad (4)$$

Angular velocity or acceleration of coordinate system W can be calculated as follows

$$J_2(\omega_W) = \begin{bmatrix} 1 & S(\varphi)T(\theta) & C(\varphi)T(\theta) \\ 0 & C(\varphi) & -S(\varphi) \\ 0 & S(\varphi)/C(\theta) & C(\varphi)/C(\theta) \end{bmatrix} \quad (5)$$

Every movement of the AUV can be shown in Fig. 1.

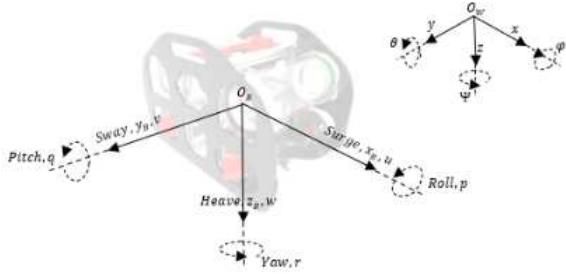


Fig 1. AUV Kinematics

### C. AUV Dynamics

A dynamic model of the AUV can be used to determine the formula of control algorithm and simulation. The AUV dynamic equation can be calculated as [11]

$$M\dot{V} + C(V)V + D(V)V + g(\eta) = \tau. \quad (6)$$

Equation (9) is derived from Newton-Euler equation of rigid body in fluid [12], where  $M = M_{RB} + M_A$  denotes inertia and added mass matrix,  $C(V) = C_{RB}(V) + C_A(V)$  denotes the Coriolis and centripetal matrix for the rigid body and added mass,  $D(V) = D_q(V) + D_l(V)$  denotes quadratic and linear drag matrix,  $g(\eta)$  denotes weight and buoyancy matrix, and  $\tau$  is force or torque vector from the thrusters.

### D. PID Control System

PID controller can be used in the control system of AUV. Each parameter of the PID, such as Proportional, Integral, and Derivative has the constant values of  $K_p$  (Proportional constant),  $K_i$  (Integral constant), and  $K_d$  (Derivative constant), respectively. The equation of PID controller can be written as,

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt}, \quad (7)$$

where  $u(t)$  is the output from the system,  $e$  is error,  $t$  is the time, and  $\tau$  is an integral variable with the value from 0 to  $t$ .

### III. RESEARCH METHOD

This method performed in this study is divided into three parts, namely control system, hardware design, and system testing design. To test of AUV was conducted in a lake.

### A. Control System

The block diagram of the control system performed in this study can be seen in Fig. 2. The setpoints for surge, heave, and yaw movement are  $x$ ,  $z$ ,  $\Psi$ , respectively while  $x^*$ ,  $z^*$ , and  $\Psi^*$  are the output of the control system. A bilge pump is the thruster of the AUV and the sensors are acceleration, gyroscope, and pressure sensor.

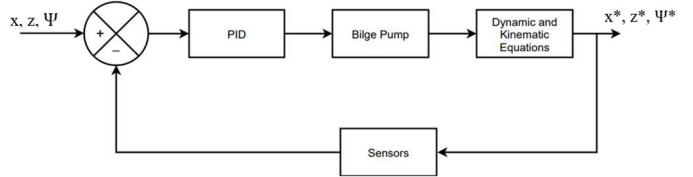


Fig 2. System design

### B. Hardware Design

The design of the AUV can be seen in Fig. 3. The AUV uses 2 acrylic tubes with 5 mm width, an aluminum rod, an acrylic base, and 6 bilge pumps for the thrusters and buoy.

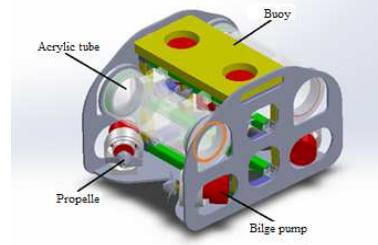


Fig 3. AUV Design

### C. System Testing

The testing was conducted to know the success and errors of the system that has been designed. In the AUV testing process, a depth setpoint was given, then the AUV moved trying to reach a setpoint while maintaining its position and stability. The testing was also conducted to know some parameters, such as overshoot, delay time, peak time, settling time, and rise time. These parameters were used to analyze and declare whether the system was good.

### IV. RESULTS AND DISCUSSION

This section discusses testing and analysis of the AUV position control systems using the PID controller, and the prototype of AUV.

#### A. AUV Prototype

The AUV was manufactured before conducting the testing. In this research, the AUV was assembled by aluminum rod, acrylic, acrylic tube, and plastic bottles. The AUV that has been made is shown in Fig. 4.



Fig 4. AUV Prototype

## B. AUV Design For Simulation

The simulation was conducted to the AUV design to know the values of linear drag, quadratic drag, and added mass of the AUV. Ansys Fluent and Ansys Aqwa were used for the simulation. Ansys Fluent was used to know the value of linear drag and quadratic drag for surge, heave, and yaw movement while Ansys Aqwa was used to know the value of added mass for surge, heave, and yaw movement. First, the design of AUV must be simplified as seen in Fig. 5.



Fig 5. AUV Design For Simulation

Measurement and simulation results using Solidworks, Ansys Fluent, and Ansys Aqwa can be seen in Table I.

TABLE I. MEASUREMENT AND SIMULATION RESULTS OF AUV

Mass	9.12 kg
Volume	0.005 m <sup>3</sup>
Length	40.2 cm
Width	29 cm
Height	27.1 cm
I <sub>xx</sub> (Moment of inertia in x axis)	0.088 kg/m <sup>2</sup>
I <sub>yy</sub> (Moment of inertia in y axis)	0.110 kg/m <sup>2</sup>
I <sub>zz</sub> (Moment of inertia in z axis)	0.097 kg/m <sup>2</sup>
Weight	89.4672 N
Buoyancy	48.9519 N
X <sub>u</sub> (Linear drag surge)	2.80059 Ns/m
Z <sub>w</sub> (Linear drag heave)	0.1416 Ns/m
N <sub>r</sub> (Linear drag yaw)	0.0114290 Ns/m
X <sub>u u </sub> (Quadratic drag surge)	37.1787 Ns <sup>2</sup> /m <sup>2</sup>
Z <sub>w w </sub> (Quadratic drag heave)	18.758 Ns <sup>2</sup> /m <sup>2</sup>
N <sub>r r </sub> (Quadratic drag yaw)	0.9140965 Ns <sup>2</sup> /m <sup>2</sup>
X <sub>u</sub> (Added mass surge)	6.267665 kg
Z <sub>w</sub> (Added mass heave)	18.93234 kg
N <sub>r</sub> (Added mass yaw)	0.00242 kg

## C. AUV Simulation using PID Controller

The simulation and testing of the AUV using the PID controller were conducted in Simulink. There are some assumptions applied to simplify the control system of AUV. The assumptions are:

1. Buoyancy of AUV is neglected because AUV moves relatively slow.
2. Symmetric in 3 planes, x-z, y-z, and x-y plane.
3. Roll, Pitch, and Sway movements are neglected because the AUV in this research cannot do that movements.
4. The B-frame is positioned at the center of gravity, therefore  $r_G = [0 \ 0 \ 0]^T$ .
5. DOF (Degrees of Freedom) of the AUV can be decoupled, this assumes that motion along one DOF does not affect another DOF. When DOF are decoupled the Coriolis and centripetal matrix becomes negligible, since only diagonal terms matter [9], therefore the dynamic model of the AUV becomes

$$M\dot{V} + D(V)V + g(\eta) = \tau. \quad (8)$$

Based on the above assumptions, dynamic equation in the surge, heave, and yaw movements of the AUV become

*Surge:*

$$(m - X_u)\dot{u} = g_x + X_u u + X_{u|u|}u| + \tau_u, \quad (9)$$

*Heave:*

$$(m - Z_w)\dot{w} = g_z + Z_w w + Z_{w|w|}w| + \tau_w, \quad (10)$$

*Yaw:*

$$(I_{zz} - N_r)\dot{r} = g_\Psi + N_r r + N_{r|r|}r| + \tau_r, \quad (11)$$

where  $\tau_u$ ,  $\tau_w$ , and  $\tau_r$  are the thruster force in surge, heave, and yaw movement, respectively, while  $\dot{u}$ ,  $\dot{w}$ , and  $\dot{r}$  are AUV acceleration in surge, heave, and yaw movement, respectively. Kinematic equations for surge, heave, and yaw movement of the AUV become [13-14]

$$\dot{x} = u \cos(\Psi), \quad (12)$$

$$\dot{z} = w, \quad (13)$$

$$\Psi = r. \quad (14)$$

where  $\dot{x}$ ,  $\dot{z}$ , and  $\dot{\Psi}$  are AUV velocity in surge, heave and yaw movement, respectively. Dynamic and kinematic equations were used in the simulation. The simulation was conducted in Simulink using some blocks, such as Matlab Function, Integrator, Derivative, Gain, Scope, Constant, Limit, and Sum. Fig. 6 shows the simulation model of AUV in the Simulink.

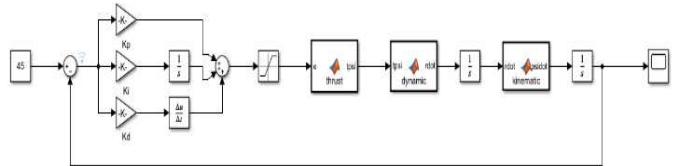


Fig 6. Model simulation of AUV in Simulink

The gain value of the PID controller was determined using trial and error method. Table II shows the gain value of the PID controller.

TABLE II. GAIN VALUE OF PID CONTROLLER

Movement	K <sub>p</sub>	K <sub>i</sub>	K <sub>d</sub>
Surge	38.41	10.8	58.4
Heave	49.13	2.56	107.12
Yaw	3.18	0.18	12.11

Simulation was conducted by giving the setpoint of  $x = 1$  m,  $z = 0.5$  m, and  $\Psi = 45^\circ$ . The simulation results using the PID gain value in Table II are shown in Figs. 7, 8, and 9 with surge, heave, and yaw movement, respectively.

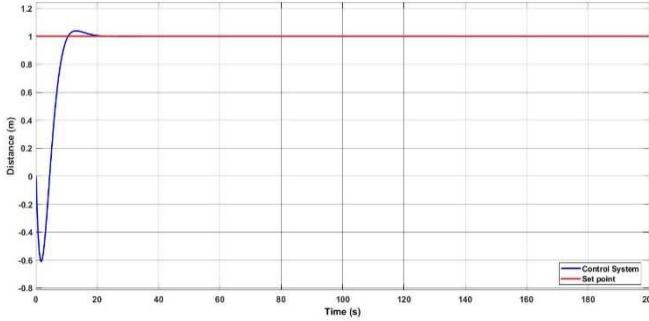


Fig 7. Simulation result in surge movement

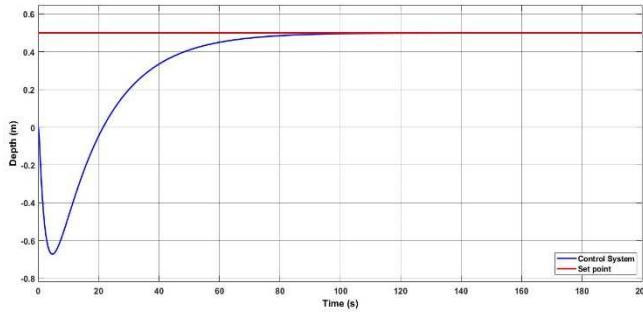


Fig 8. Simulation result in heave movement

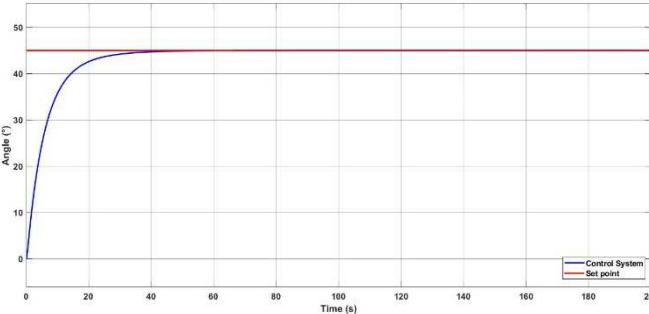


Fig 9. Simulation result in yaw movement

Table III shows more detail of simulation results shown in Figs. 7, 8, and 9.

TABLE III. SIMULATION RESULTS USING SIMULINK

Parameter	Surge	Heave	Yaw
Delay time	8.07 s	33.048 s	4.47 s
Rise time	10.51 s	174.012 s	88.91s
Settling time	19.68 s	73.164 s	17.65 s
Peak time	12.71 s	200 s	58.45 s
Overshoot	3.77 %	0.0035 %	0.015 %

#### D. AUV test using PID Controller

The gain values of the PID Controller in Table II are used in the testing. The testing was conducted in the lake, and the setpoints of the surge movement, heave movement, and yaw movement were 0 cm, 50 cm, and 0°, respectively. The test results are shown in Figs. 10, 11, 12 for surge, heave, and yaw movements.

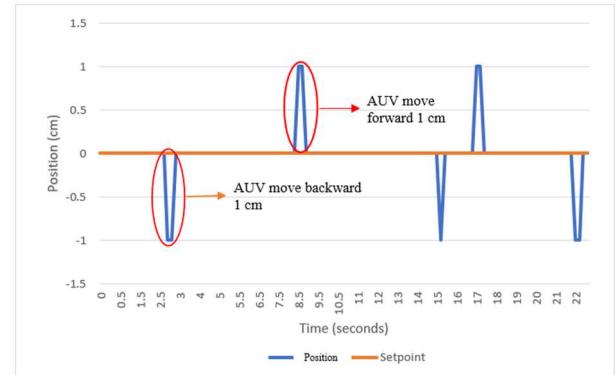


Fig 10. Surge movement test.

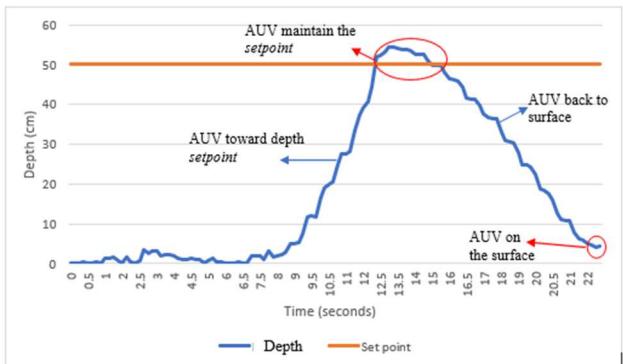


Fig 11. Heave movement test

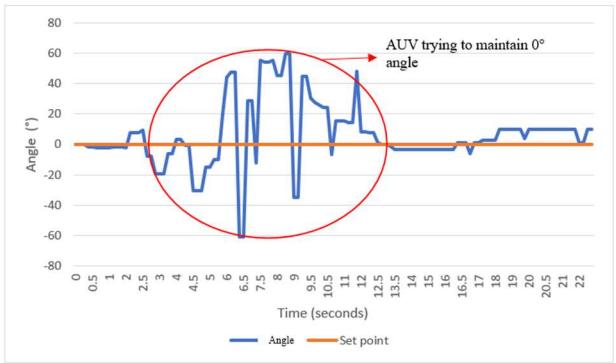


Fig 12. Yaw movement test

Based on Figs. 10, 11, and 12, the testing duration is 22.5 seconds. In surge movement, the AUV can maintain its position well, with an error of  $\pm 1$  cm. In heave movement, the AUV can reach the setpoint of 50 cm within 12 seconds and maintain its position about 3.5 seconds before the AUV went up to the surface in 7 seconds. In yaw movement, the error was a large error about  $-60^\circ$  and  $60^\circ$ , this is due to the sensor poor in readings the values within a certain time. Even though it has a fairly large error value, the AUV can still move towards the specified setpoint.

#### V. CONCLUSION

Based on the simulation and test of the AUV, it can be concluded that the PID controller implemented on the AUV can work well. The gain values of the AUV were  $K_p = 38.41$ ,  $K_i = 10.8$ , and  $K_d = 58.4$  for surge movement,  $K_p = 49.13$ ,  $K_i = 2.56$ , and  $K_d = 107.12$  for heave movement, and  $K_p = 3.18$ ,  $K_i = 0.18$ , and  $K_d = 12.11$  for yaw movement. The

simulation results in Simulink showed that the settling time for surge movement was 19.68 seconds, for heave movement is 73.164 seconds, and for yaw movement in 17.65 seconds, while the AUV test showed that the AUV can maintain its position around 3 – 4 seconds at depth of 50 cm and able to maintain 0° for a few seconds.

For future works, the AUV simulation design should not be simplified to generate the best result in computation and simulation. Besides, an additional controller or use of another controller should be done to make the AUV navigation and position better.

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