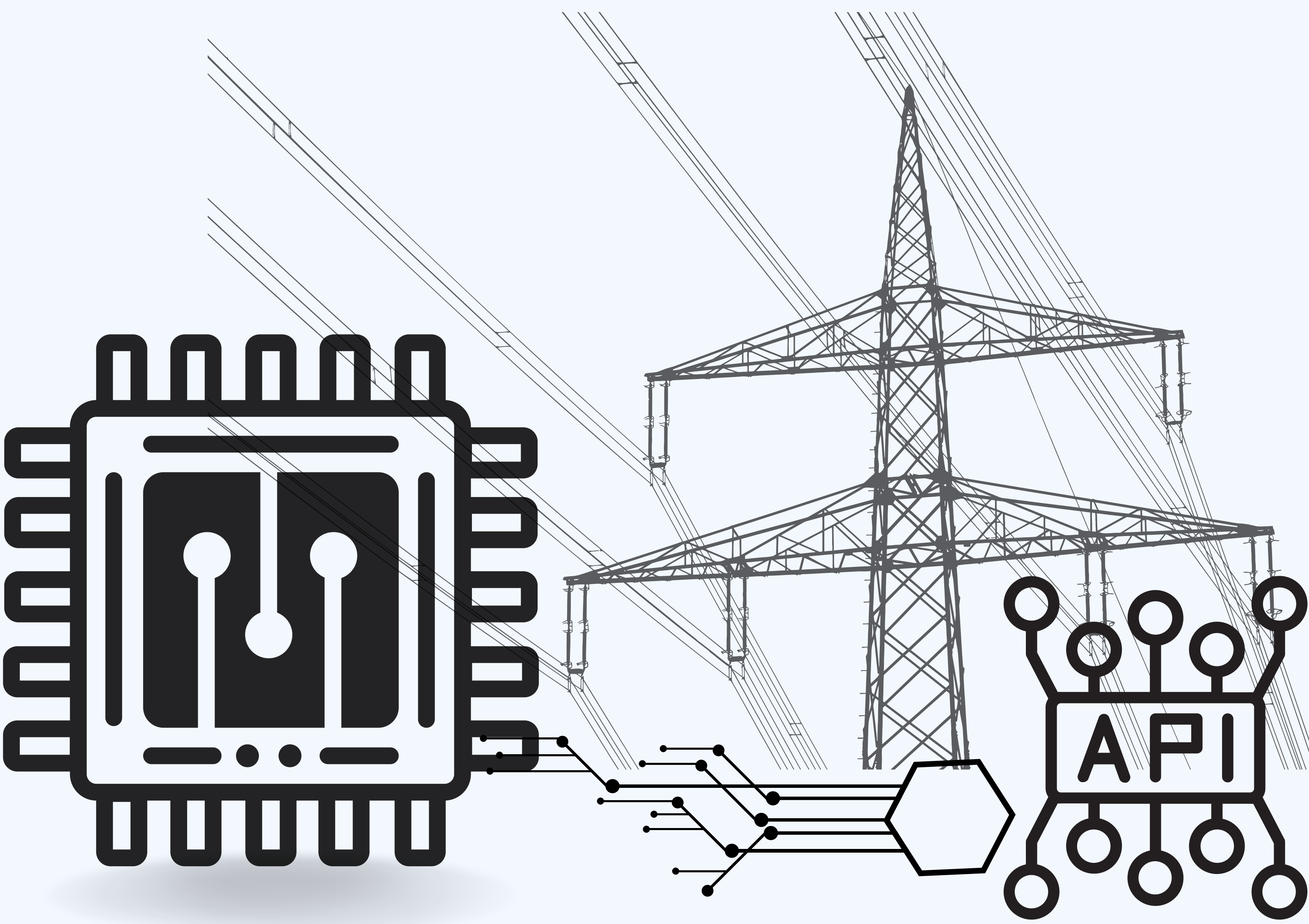
ICITACEE 2023

THE 10TH INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGY, COMPUTER, AND ELECTRICAL ENGINEERING

PROCEEDINGS



Artificial intelligence for eco-friendly technologies and humanities

icitacee.undip.ac.id

Organized by:

Department of Computer Engineering
Faculty of Engineering
Diponegoro University, Indonesia

Technical Co-Sponsored by:

IEEE INDONESIA SECTION

Proceedings

2023 10th International Conference on Information Technology, Computer and Electrical Engineering

(ICITACEE)

Editor:
Ilmam Fauzi Hashbil Alim
Bellia Dwi Cahya Putri

Proceedings
2023 10th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE)

Publisher:
Department of Computer Engineering
Diponegoro University

ISBN: 979-8-3503-2271-2 (USB, Part Number: CFP2389Z-USB)
ISBN: 979-8-3503-2272-9 (XPLORE COMPLIANT, Part Number: CFP2389Z-ART)

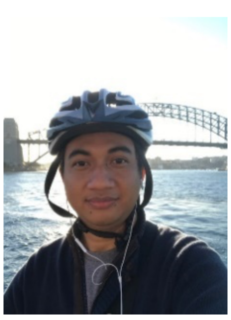
Additional copies may be ordered to:
Department of Computer Engineering
Diponegoro University,
Jl. Prof. H. Soedarto, S.H., Tembalang
Semarang, Indonesia 50275

GREETINGS FROM THE GENERAL CHAIR

Welcome to the 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE). ICITACEE is a yearly event hosted by the Faculty of Engineering, Universitas Diponegoro, and operated by the Department of Computer Engineering and Department of Electrical Engineering. This year, ICITACEE is organized by Department of Computer Engineering and offers a cross-diciplinary forum for researhers in the field of Information and Computer Technology, Power system, Circuit and Control, Communication Sytems, and Green Technologies. Through this forum, it is expected that all participants can interact and disseminate the latest issues and findings based on their recent research.

The ICITACEE 2023 is held in Grand Candi Hotel, Semarang, on August 31st – September 1st, 2023. We received more than 140 papers to be reviewed, and the acceptance rate is 65% which means that only 89 papers are accepted. Geographically, researchers from 12 countries are involved in this event, and papers that have been presented, will be submitted to IEEE Xplore to be published. In this event, we also invited keynote speakers including Professor Suhaidi Hassan from Universiti Utara Malaysia, Assoc. Professor Haiyan Lu from University of Technology Sydney Australia, Jusuf Sjariffuding the founder and CEO of Indivara Group, and Assoc. Professor Aghus Sofwan from Universitas Diponegoro. We believe that the idea shared with us in this event can provide an insight regarding the future direction of research in the artificial intelligence field.

Finally, we would like to thank to our standing committee who made this event possible. We also like to say our gratitude to all staffs of Department of Computer Engineering and Department of Electrical Engineering Universitas Diponegoro for their continuous supports on this event. Moreover, our special thanks goes to the IEEE Indonesia Section, reviewers, authors, chair members, committee members, and other volunteers and participants who provide kind assistance on all aspects of the conference. I hope everyone can enjoy this event, and it would be a pleasure to see you again on the 2024 ICITACEE.



Rinta Kridalukmana, S.Kom., M.T., Ph.D
General Chair
2023 10th International Conference of Information Technology, Computer, and Electrical Engineering (ICITACEE)

FOREWORD FROM HEAD OF DEPARTMENT OF COMPUTER ENGINEERING, UNIVERSITAS DIPONEGORO, SEMARANG – INDONESIA

Welcome to all the participants in The 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE 2023) at Grand Candi Hotel, Semarang, Indonesia.

I would like to welcome keynote speakers from the University Utara Malaysia, the University of Technology Sydney, Founder, President, and CEO of Indivara Group, and Diponegoro University.

This is the tenth conference by the Computer Engineering Department and Electrical Engineering Department of Engineering Faculty, Universitas Diponegoro. I appreciate the vast work at this conference as a collaborative effort among the Computer Engineering Department, Electrical Engineering Department, Universitas Diponegoro, and IEEE Indonesia Section. This conference will be a prestigious forum to communicate and share the findings and precious research among computer, information technology, and electrical engineering experts. I want to express my deep appreciation to the Organizing Committee members, staff, and students of the Computer Engineering and Electrical Engineering Department of Universitas Diponegoro for their effort and support. This event will give a contribution to the global development of Computer Engineering as well as Electrical Engineering.

Dr. Adian Fatchur Rochim, S.T., M.T., SMIEEE.
Head of Department of Computer Engineering
Faculty of Engineering – Diponegoro University
Semarang – Indonesia

FOREWORD FROM DEAN OF FACULTY OF ENGINEERING UNIVERSITAS DIPONEGORO, SEMARANG – INDONESIA

The 2023 10th International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE 2023) is now held again as an annual conference organized by Department of Computer Diponegoro University.

The conference aims to provide a forum for researchers, academicians, professionals, and students from various engineering fields with cross-disciplinary working or interest in developing and designing information technology, computers, and electrical engineering to interact and disseminate the latest issues and researchers.

ICITACEE 2023 also invites scholars and encourages researchers to submit high-quality manuscripts and papers to this conference. It is also to share and exchange ideas, thoughts, and discussions on all aspects of the development and design of information technology, computers, and electrical engineering to facilitate the formation of networks among participants of the conference for improving the quality and benefits of the research.

It is a great pleasure to welcome all the participants of this conference in Semarang. I also welcome the keynote speakers from the University Utara Malaysia, the University of Technology Sydney, the Founder, President, and CEO of Indivara Group, and Diponegoro University. This conference will be a valuable forum for engineers and scientists to share their precious research, and this event will give significant contributions to the development of Information Technology, Computer, and Electrical Engineering. It will raise the awareness of scientific community members in bringing better life.

I hope that the conference will be stimulating and memorable for you. So, enjoy your time in Semarang.

Prof. Ir. M. Agung Wibowo, MM, MSc, PhD
Dean of Faculty of Engineering
Diponegoro University
Semarang – Indonesia

ICITACEE Committee

General Chair : Rinta Kridalukmana

Co-Chair : Wahyudi

Organizing Committee:

Dania Eridani

Bellia Dwi Cahya Putri

Rizal Isnanto

Oky Dwi Nurhayati

Risma Septiana

Ratna Rissanti

Yosua Alvin Adi Soetrisno

Patricia Evericho Mountaines

Adnan Fauzi

Arseto Satriyo Nugroho

Steering Committee:

Wahyudi Hasbi (IEEE Indonesia Section)

Siswo Sumardiono (Faculty of Engineering Universitas Diponegoro)

Adian F. Rochim (Department of Computer Engineering Universitas Diponegoro)

Technical Programming Committee:

Achmad Basuki, S.T., M.MG., Ph.D. (Brawijaya University)

Hendry, S.T., M.T. Ph.D (Universitas Kristen Satya Wacana)

Imamul Muttakin (CTECH Labs Edwar Technology Co.)

Dr. Tessy Badriyah (Electronic Engineering Polytechnic Institute of Surabaya)

Dr. Raden Dewanto (Electronic Engineering Polytechnic Institute of Surabaya)

Dr. Arman Jaya (Electronics Engineering Polytechnic Institute of Surabaya)

Dr. Muzaffar Hamzah (Fakulti Komputeran dan Informatik)

Dr. Amil Ahmad Ilham (Hasanuddin University)

Prof. Bahniman Ghosh (IIT Kanpur)

Julianto Lemantara (Institut Bisnis dan Informatika Stikom Surabaya)

Prof. Trio Adiono (Institut Teknologi Bandung)

Dr. Widyawardana Adiprawita, S.T, M.T. (Institut Teknologi Bandung)

Dr. Yoanes Bandung, S.T, M.T. (Institut Teknologi Bandung)

Prof. Ir. Endra Joelianto, Ph.D. (Institut Teknologi Bandung)

Dr. Trihastuti Agustinah, S.T., M.T. (Institut Teknologi Sepuluh Nopember)

Dr. Dhany Arifianto, S.T., M.Eng. (Institut Teknologi Sepuluh Nopember)

Prof. Dr. Agus Zainal Arifin, S.Kom., M.Kom. (Institut Teknologi Sepuluh Nopember)

Dr. Dimas Asfani (Institut Teknologi Sepuluh Nopember)

Dr. Irmalia Faradisa (Institut Teknologi Sepuluh Nopember)

Prof. Gamantyo Hendrantoro (Institut Teknologi Sepuluh Nopember)

Dr. Darlis Herumurti (Institut Teknologi Sepuluh Nopember)

Dr. Ronny Mardiyanto (Institut Teknologi Sepuluh Nopember)

Dr. Djoko Purwanto (Institut Teknologi Sepuluh Nopember)

Prof. Tohari Ahmad (Institut Teknologi Sepuluh Nopember)

Dr. Achmad Arifin (Institut Teknologi Sepuluh Nopember)

Dr. Wibawa Adhi (Institut Teknologi Sepuluh Nopember)

Dr. Mochammad Rameli (Institut Teknologi Sepuluh Nopember)

Izza Anshory (Institute Teknologi Sepuluh Nopember)

Hosein Farzanehfard (Isfahan University of Technology)

Dr. Adit Kurniawan (Institut Teknologi Bandung)

Dr. E Endroyono (Institute Teknologi Sepuluh Nopember)

Dr. Om Kumar (Jawaharlal Nehru Technological University Anantapur PGDSE)

Dr. Awais Mahmood (King Saud University)

Prof. Masayuki Hikita (Kyusyu Institute of Technology)

Dr. Anik Handayani (Malang State University)

Dr. Harishchandra Dubey (Microsoft Corporation)

Dr. Somya Mohanty (MNIT Allahabad)

Kuntoro Nugroho (National Taiwan University of Science and Technology)

Dr. Norshita Mat Nayan (National University of Malaysia)

Dr. Zainal Arif (Politeknik Elektronika Negeri Surabaya)

Dr. I Gede Puja Astawa (Politeknik Elektronika Negeri Surabaya)

Dr. Ali Barakbah (Politeknik Elektronika Negeri Surabaya)
Dr. Dedid Happyanto (Politeknik Elektronika Negeri Surabaya)
Dr. Son Kuswadi (Politeknik Elektronika Negeri Surabaya)
Dr. M. Udin Harun Al Rasyid (Politeknik Elektronika Negeri Surabaya (PENS))
Dr. Agus Indra Gunawan (Politeknik Elektronika Negeri Surabaya (PENS))
Dr. Prima Kristalina (Politeknik Elektronika Negeri Surabaya (PENS))
Dr. Rosa Asmara (Politeknik Negeri Malang)
Dr. Cahya Rahmad (Politeknik Negeri Malang)
Dwiana Hendrawati (Politeknik Negeri Semarang)
Dr. Sidiq Hidayat (Politeknik Negeri Semarang)
Amiruddin Amiruddin (Politeknik Siber dan Sandi Negara)
Magfirawaty Magfirawaty (Politeknik Siber dan Sandi Negara)
Dr. Edi Kurniawan (Research Center for Informatics LIPI)
Prof. Eko Sediyono (Satyawacana Christian University)
Mochamad Hariadi (Institute Teknologi Sepuluh Nopember)
Supeno Mardi Susiki Nugroho (Institute Teknologi Sepuluh Nopember)
Prof. Mochamad Ashari (Institute Teknologi Sepuluh Nopember)
Dr. Rizal Munadi (Syiah Kuala University)
Andreas Aabrandt (Technical University of Denmark)
Prof. A Adiwijaya (Telkom University)
Dr. Khoirul Anwar (Telkom University)
Soni Gumilang (Telkom University)
Dr. Lie Jasa (Udayana University)
Dr. Khabib Mustofa (Universitas Gadjahmada)
Dr. Muhannad Alshareef (Umm Al-Qura University)
Dr. Suryani Alifah (Unissula University)
Dr. Nazrulazhar Bahaman (Univeristi Teknikal Malaysia Melaka)
Muhamad Iradat Achmad (Universitas Gadjah Mada)
Dr. Teguh Adji (Universitas Gadjah Mada)
Paulus Insap Santosa (Universitas Gadjah Mada)
Dr. Lukito Nugroho (Universitas Gadjah Mada)
Dr. Radi Radi (Universitas Gadjah Mada)
Dr. Paulus Santosa (Universitas Gadjah Mada)
Dr. Noor Akhmad Setiawan (Universitas Gadjah Mada)
Dr. Muhammad Niswar (Universitas Hasanuddin)
Dr. Muhamad Asvial (Universitas Indonesia)
Dr. Basari Basari (Universitas Indonesia)
Dr. Dadang Gunawan (Universitas Indonesia)
Dr. Ruki Harwahyu (Universitas Indonesia)
Faiz Husnayain (Universitas Indonesia)
Misbahuddin (Universitas Indonesia)
Dr. Abdul Muis(Universitas Indonesia)

Dr. Mukhammad Andri Setiawan (Universitas Islam Indonesia)

Dr. Izzati Muhimmah (Universitas Islam Indonesia)

Imam Much Ibnu Subroto (Universitas Islam Sultan Agung)

Dr. Muhammad Qomaruddin (Universitas Islam Sultan Agung (UNISSULA))

Iis Hamsir Wahab (Universitas Khairun)

Dr. Hamzah Eteruddin (Universitas Lancang Kuning)

Dr. Subiyanto (Universitas Negeri Semarang)

Moh Khairudin(Universitas Negeri Yogyakarta)

Dr. Iswadi Hasyim Rosma (Universitas Riau)

Muhammad 'Irfan Jambak (Universitas Sriwijaya)

Fahmi Fahmi (Universitas Sumatera Utara)

Dr. Melinda Nurdin (Universitas Syiah Kuala)

Dr. Muhammad Anshari (Universiti Brunei Darussalam)

Zuriani Hayati Abdullah (Universiti Kebangsaan Malaysia)

Haniza Nahar (Universiti Teknikal Malaysia)

Dr. Mohd Fairuz Iskandar Othman (Universiti Teknikal Malaysia Melaka)

Dr. Sharul Kamal A. Rahim (Universiti Teknologi Malaysia)

Dr. Mohd Junaidi Abd Aziz (Universiti Teknologi Malaysia)

Zolkafle Buntat (Universiti Teknologi Malaysia)

Dr. Norsheila Fisal (Universiti Teknologi Malaysia)

Prof. Razali Ismail (Universiti Teknologi Malaysia)

Dr. Intan Mat Darus (Universiti Teknologi Malaysia)

Ade Erawan Minhat (Universiti Teknologi Malaysia)

Mohd Helmy Abd Wahab (Universiti Tun Hussein Onn Malaysia)

Hindarto Hindarto (University Muhammadiyah Of Sidoarjo)

Ruri Basuki (University of Dian Nuswantoro)

Triwahju Hardianto (University of Jember)

Ferry Irawan (University of Jember)

Dr. Dikpride Despa (University of Lampung)

Dr. Muhamad Syamsu Iqbal (University of Mataram)

Dr. Zulfatman Has (University of Muhammadiyah Malang)

Dr. Reza Firsandaya Malik (University of Sriwijaya)

Dr. Mohsen Naderpour (University of Technology Sydney)

Dr. Fahimeh Ramezani (University of Technology Sydney)

KEYNOTE SPEAKER

<table>
<tr><th colspan="2">KEYNOTE SPEAKER 1</th></tr>
<tr><td></td><td>PROF. DR. SUHAIDI HASSAN, Ph.D., PTech FAPM, SMIEEE
Universiti Utara Malaysia

Keynote Title:
Embracing Digital Transformation Towards the Internet of the Future: Emerging Technologies, Potentials and Challenges</td></tr>
<tr><td colspan="2">Prof. Dr. Suhaidi Hassan is a tenure track professor in computer and communication networks at Universiti Utara Malaysia (UUM. He holds a bachelor's degree in computer science from the State University of New York in Binghamton, a master's degree in information science from the University of Pittsburgh, and a Ph.D. in computing from the University of Leeds. He is the founding chairman of the UUM InterNetWorks Research Laboratory. Prof. Hassan is a fellow of the Academy of Professors Malaysia and has served as the founding President of the Internet Society Malaysia. With over 300 scholarlyindexed refereed technical publications to his name and 27 successful Ph.D. supervisions in his field of expertise, Prof. Hassan is an accomplished researcher and mentor. He has also served on numerous national and international committees and councils, including the Malaysian Research and Educational Network (MYREN) and the Malaysian ICT Deans Council. In 2006, he led an initiative to establish an International Telecommunication Union (ITU)-UUM AsiaPacific Centre of Excellence for Rural ICT Development. Prof. Hassan is also an active participant in international forums such as ICANN meetings, Internet Governance Forums, and IETF meetings.</td></tr>
</table>

KEYNOTE SPEAKER 2

Assoc. Professor Haiyan Lu

University of Technology Sydney, Australia

Keynote Title:
Skeleton-based Human Action Recognition: From 3D Pose Estimation to Action Recognition

Dr Haiyan (Helen) Lu is an associate professor, the Head of Discipline of Data Analytics and AI (Artificial Intelligence), in the School of Computer Science, Faculty of Engineering and Information Technology, University of Technology Sydney (UTS), Australia. She is a core member of the Decision Systems and e-Service Intelligence Research Laboratory in the Australian Artificial Intelligence Institute at the University of Technology Sydney (UTS).

She received her Bachelor and master's degrees in Harbin Institute of Technology (HIT) China in 1985 and 1988, respectively, and PhD degree from the University of Technology Sydney in 2002. She is a senior member of IEEE.

Her main research interests are heuristic optimization techniques, machine learning, forecasting and prediction of time series, ontology-based knowledge representation, recommendation systems.

She has contributed to total 195 publications, including 3 book chapters, 102 refereed journal articles and 90 refereed international conference papers in the following four research areas:

- Statistical learning algorithms, computational intelligence (especially heuristic global search algorithms) and machine learning techniques for time series forecasting and scheduling problems in smart grid applications.
- Ontology based knowledge representation and modelling for intelligent Information Systems for smart e-service systems.
- Design and simulation of electromagnetic devices with a focus on modelling of magnetic materials
- Edge computing for smart IoT systems in smart grid applications

KEYNOTE SPEAKER 3

Jusuf Sjariffudin
Founder, President, and CEO of Indivara Group

Keynote Title:
Helping BPRs and UMKM goes digital

Jusuf Sjariffudin is the Founder, President, and CEO of PT Indivara Sejahtera Sukses Makmur (Indivara Group), responsible for determining the firm’s overall strategic direction as well as the management of the company to ensure long-term and sustainable profitability.

Prior to founding Indivara, Jusuf founded Jatis in 1997. Under his leadership Jatis enjoys significant growth and becomes a dominant technology solution provider in Indonesia and is increasingly replicating that success across the region. In 2015 Jusuf founded Indivara and consolidated Jatis and all other technology companies, which he also founded, into one group. Indivara has two main divisions - Business Enabler and Platform and is one of the largest largest technology group in ASEAN with significant presence in Indonesia, Singapore, Malaysia and the Philippines.

Before being a technology entrepreneur Jusuf was with Lotus Consulting (Asia Pacific) as Chief Technology Officer and the main architect behind the firm’s Lotus Consulting Intranet framework codename Velo, which was instrumental in the achievement of its revenue target for Lotus Consulting in the Asia Pacific Region. On the business end, he was also involved in establishing Lotus Consulting Indonesia and Korea practice.

Jusuf spent his early career with Andersen Consulting as a Senior Consultant of the Technology Integration Services Group. In his position, Jusuf was responsible for providing technical consultancy services within the Financial Service and Government sectors. Jusuf Sjariffudin holds a bachelor’s degree in computer engineering from the Nanyang Technological University, Singapore.

Achievements:
- Partner Award (Andersen Consulting, 1995)
- Asia Pasific Director's Excellent Award (Lotus Consulting, 1996)
- Enterpreneur of the Year Award for Indonesia (Ernst & Young Enterpreneur of the Year Program, 2001)

KEYNOTE SPEAKER 4

Assoc. Professor Aghus Sofwan
Department of Electrical Engineering, Universitas Diponegoro

Keynote Title:
AI's role in people's daily activities

Aghus Sofwan, S.T., M.T., Ph.D. is an associate professor and The Head Department of Electrical Engineering, Engineering Faculty, Diponegoro University, Semarang, Indonesia. He is an IEEE member and has competent in Information Technology.

He received his Bachelor’s Degree in Electrical Engineering from Diponegoro University in 1995, a Master’s in Computer Science from Gadjah Mada University in 2002, and an Electrical Engineering Ph.D. from King Saud University in 2016.

His main researches are Internet of Things, Artificial Intelligent, and mobile computing. He has 151 articles published in Scopus, WoS, and Google Scholar and has 3 IPRs. His recent research discusses autonomous object recognition robots for logistic transport.

Parallel Session I Schedule
(Online/Zoom)

Parallel Class	Online
Room	Breakout Room D
Time	13.15 – 15.15
Chair	Arseto Setyo Nugroho

No	Paper ID	Title	Time	Presenter
1	1570909663	An Exploration of Emission Data Visualization in Southeast Asian Countries	13.15 – 13.27	Pattharaporn Thongnim
2	1570912174	Digital Counseling Model with Deep Learning for Mental Health of Vocational School Students	13.27 – 13.39	Agus Aan Jiwa
3	1570917057	Digital Image Forensics for Reservoir Area Changes Identification	13.39 – 13.51	Imam Yuadi
4	1570917897	Solving the Blood Assignment Problem for Hospital in Pontianak City, Indonesia Using Ant Colony Optimization	13.51 – 14.03	Menur Wahyu Pangestika
5	1570917971	Detection of Hate Speech Using Improved Deep Learning Techniques	14.03 – 14.15	Ernest Dylan G. Gloria
6	1570918003	Analysis and Evaluation of Purchase Intention Factors in Social Commerce in Indonesia	14.15 – 14.27	Vinson Leo Veronal Jong
7	1570918289	CheckApp: A Web-Based Multipurpose Telemedicine System for E-Checkups and Face-To-Face Consultations	14.27 – 14.39	Fritz L. Tuazon
8	1570919692	Improved Immersive Virtual Reality (VR) Using Image Enhancement Method	14.39 – 14.51	I Gede Partha Sindu
9	1570920781	Performance Comparison of AES, Grain V1, and RC4 Algorithms on the MQTT Protocol	14.51 – 15.03	Saffira Syafa Nugrahani
10	1570920856	Remote-Controlled Lawn Mower Powered by Solar Panel with Sun Tracking System	15.03 – 15.15	Ralph Gabucan Enogaling

Table of Contents

Improved Immersive Virtual Reality (VR) using Image Enhancement Method

I Gede Partha Sindu
Dept. of Informatics
Universitas Pendidikan Ganesha
Singaraja, Bali, Indonesia
partha.sindu@undiksha.ac.id

Rukmi Sari Hartati
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
rukmisari@unud.ac.id

Made Sudarma
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
msudarma@unud.ac.id

Nyoman Gunantara
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
gunantara@unud.ac.id

***Abstract*—The research aims to enhance immersive VR through improved design display quality in virtual environments. It is grounded in the image problem because in the virtual environment, there is a difference in color contrast 3D design interior and exterior environments of residential with a real view of the interior and external environments of buildings. So the results of the design of the interior and exterior environments of housing are still not immersive and do not look natural or real. The method used is image enhancement consisting of Histogram Enhancement (HE), Contrast-Limited Adaptive Histogram (CLAHE), and Fuzzy Contrast Enhancement (FCE). The data used in this study totaled 3.157 images in PNG format with a resolution of 512 x 512. The stages of this study start with data finalization, the image enhancement process, and evaluation. Through the investigative process, CLAHE method is able to outperform HE and FCE with an average of Structural Similarity Index (SSIM) 0.959, Image Quality Index (IQI) 0.959, through Mean Squared Error (MSE) 0.003, Root Mean Squared Error (RMSE) 0.055, and Peak Signal-to-Noise Ratio (PSNR) 25.705. Additional parameters, such as tiles generation and clip limit, on CLAHE can improve the image quality of the virtual environment without causing over-enhancement.**

Keywords— Immersive VR, Image Enhancement, HE, CLAHE

I. Introduction

Virtual Reality (VR) is a technology that has the benefit of providing in-depth knowledge and experiences to its users [1]. The main advantage of VR is the experience that makes users feel the sensations of the real world in the virtual world [2], [3]. With VR, the user is brought to another dimension whose state depiction resembles the original shape of the object, while the reality is that the user remains in the same place. One of the key elements of the VR environment is immersion [4]. Immersive in the virtual environment is a technology where the entire walls and floors of a room are projected with moving images that are equipped with sound so that visitors can experience a unique and exciting experience [5]. These moving images should be designed to resemble the original as seen in the real world. So the perception of physical presence in the virtual environment becomes increasingly real. The application of VR immersive has been widely used in various fields of education, engineering, science, medicine, and others [6]–[9].

The application of VR in the field of education, especially in the study and making of 3D design, still encounters some barriers, especially from the side of making the color texture image design of the virtual environment look real and natural. In the process of creating 3D textures using the applications Blender and Sketchup. However, the results have not yet been able to make the interior and exterior design of the home look real and natural. So a method is needed to improve the quality of the 3D texturing. The application used to display the results of this 3D texturing design uses the Mozilla Hubs platform. The Mozilla Hubs platform is able to display 3D design results using virtual reality tools. The VR tool is called Oqulus Quest 2.

At the stage of creation, VR has a complex flow and needs. Before moving to the Mozilla Hubs platform, the 3D asset created must go through a process of minimizing 3D file size to optimize the performance of VR technology on Mozilla Hubs. In the first step of research, we have already modeled the interior and exterior environments of resedential using Sketchup. The next step is to fix abnormalities in the Sketchup modeling process using Blender. The development carried out needs to pay attention to the use of material units such as vegetation, landscape, plants, furniture, and texture. The material units used have been selected and re-adjusted to have a small file size without reducing the color appearance of the interior and exterior environment designs. The image problem in the virtual environment is a difference in color contrast 3D design interior and exterior environment of residential with a real view of the interior and external environment of the residential. This causes the results of residential interior and exterior environment design images to still not be immersive and do not look natural so it is necessary to improve image quality in the virtual environment. Through the image enhancement approach, each frame of the virtual environment will be processed using Image Enhancement Algorithms including HE, CLAHE, and FCE. Each of these image enhancement algorithms will be compared to produce the best image enhancement algorithm to increase immersion in the virtual environment.

In the next section, we present research related to Part II. In Part III, we present the stages of this research. In Part IV, we present the findings and discussions, and last in Part V we deliver the conclusions and subsequent work.

II. Related Works

There are several previous studies that investigated image quality improvement and enhancement. Dominic et al. [10] conducted image enhancement experiments with the goal of extracting hidden information from images in their paper. The methods in this paper include HE, Adaptive Histogram Equalization (AHE), and CLAHE which are applied to dark images with lots of noise. Through the results of the investigation, the best enhancement results were obtained in the HE method, with an IQI of 68% and a SI of 31%. The use of the CLAHE method was also proposed by Yussof et al. [11] in their research by combining it with Bilateral Filtering to increase the contrast of the crescent moon image. This study demonstrated the ability of CLAHE and Bilateral Filtering to increase contrast with a PSNR value of 66.48% and an MSE of 0.01. The FCE method is also utilized in the case of image enhancement as proposed by Mittal et al. [12] with an in-depth discussion of FCE to improve image quality. Samrudh et al. [13] in their experiments showed that the FCE method is able to outperform the HE method using the PSNR evaluation.

In addition to improving the quality of digital images of real objects, quality improvements have also led to 3D objects. Sui et al. [14] in their study applied image enhancement to game animation designs. Through the Q-Learning method, the scene display in the game becomes more comfortable to look at and looks natural. The application of image enhancement to 3D animation was also proposed by Liu et al. [15]. Through the proposed algorithm, the highest PSNR is 72.88%. and the MSE is 0.362. Whereas in VR, image enhancement is also implemented to improve display quality. Dhaya [16] proposed Multi Scale Retinex (MSR) with an average percentage of image quality of 88.8% and an error of 0.018. Jing Xu [17] proposed a deep learning method to predict each pixel of the VR display so as to give an impression. Through the questionnaires distributed, it was found that 83% of the users were very satisfied with the VR display using this method, and 16% were quite satisfied.

III. Methods

In this section, there are a series of steps that are taken to investigate the capabilities of the proposed method. The stages in this study consisted of data finalization, application of the image enhancement algorithm, and evaluation stages. The details of a series of stages are presented in the following sub-sections:

A. Data

The main data in this study was personally acquired from VR video recordings with residential interior and exterior environments. The videos were MP4 format with 1024 x 1024 resolution and 25 FPS. There are 6 videos with each duration, namely: Video 1 (4:14), Video 2 (3:50), Video 3 (5:21), Video 4 (3:03), Video 5 (2:54), Video 6 (11:15). All videos have RGB color depth. The acquired videos are shown in Fig. 1. While The details of the preprocessing stages are shown in Fig. 2.

Fig. 1. Example of data acquisition results.

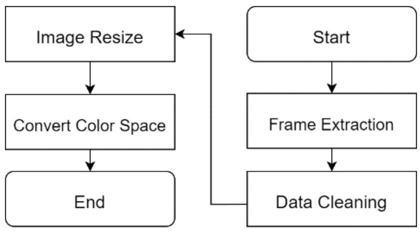


Fig. 2. Visualization of Preprocessing Stages.

Referring to Fig. 1, Each video was shot in a different place showing both the interior and exterior components of the building.

As shown in Fig. 2, each video is extracted by taking only 5 frames out of 25 frames in one second. Frame extraction resulted in 3.184 images. It then goes through data cleaning to eliminate unnecessary data. The total number of final images used is 3.157. Image resize is applied to reduce the computational load. The image is resized to 512 x 512 RGB channels. All images were then converted into LAB channels. LAB stands for L (Lightness), A (red-green color), B (yellow-blue color). This color space format is needed because the HE, CLAHE, and FCE processes require the L (Lightness) channel which is the intensity level of lightness. The L channel is made as similar as possible to the human perception of illumination [18].

B. Image Enhancement Algorithm

The image enhancement proposed in this paper consists of the HE, CLAHE, and FCE Algorithm. As for the details of each algorithm proposed in this study, as follows:

1) Histogram Equalization

Histogram Equalization (HE) is an image processing algorithm to improve image quality through an even distribution of pixel intensity so that the contrast of the image increases. The equation of HE that describes the probability of pixel i is shown in (1).

$$p_x(i) = \frac{n_i}{n}, 0 \leq i \leq L \quad (1)$$

The n_i value is the number of pixels with an intensity value, while n is the number of pixels. The value of the i intensity can be from 0 to less than L, which is the highest intensity level of 256. The value of i needs to be normalized so that it produces a value of [0, 1]. The normalization process is based on the Cumulative Probability Function (CDF) so that the intensity of all pixels is normalized [19], The equation of the CDF is shown in (2).

$$CDF(i) = \sum_{j=0}^{i} P_x(j) \quad (2)$$

In order for normalized intensity values to be visualized, the final equation shown in (3) is needed.

$$S(i) = (L-1) \times CDF(i) \quad (3)$$

$S(i)$ or the i sequence holds the value of the calculation of each pixel sequence so that a new pixel intensity distribution is formed. The visualization of the image level intensity distribution comparison after going through the HE process is shown in Fig. 3.

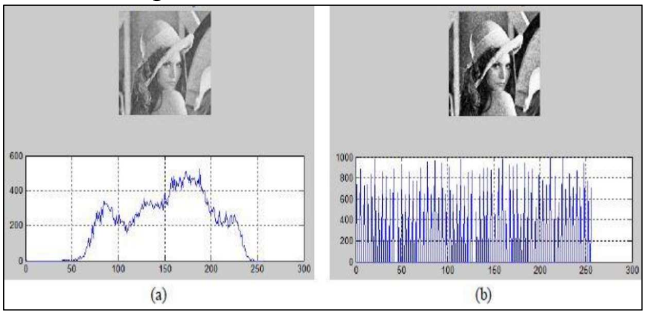


Fig. 3. Comparison between (a) the original image and (b) the image with HE [20].

Referring to Fig. 3, it can be seen that the pixel intensity is stretched so that it is evenly distributed throughout the intensity so that the contrast of the image can increase.

2) Contrast-Limited Adaptive Histogram

HE will be compared with CLAHE and FCE to find the best Image Enhancement algorithm. CLAHE was initiated to overcome the drawback of HE, which forces the distribution of pixel intensity to be equal. This results in excess contrast at both high and low intensity levels. The CLAHE process is visually shown in Fig. 4.

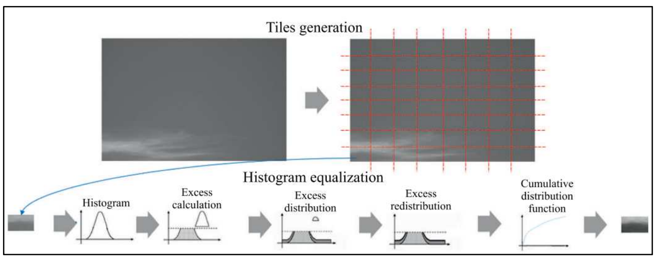


Fig. 4. CLAHE Visualization [11].

Based on Fig. 4, there are two main parts to the CLAHE process. The Tiles generation stage involves dividing the image into 16 separate parts. The 16 separate parts are obtained from the dividing parameter, which is 8 x 8. This stage serves to isolate the HE processes so they don't run on the global image. The next stage is HE on each part of the image and the clip limit parameter. The Clip parameter in the HE process is able to limit excess contrast in the pixel intensity distribution. The clip limit parameter used is 2.0.

3) Fuzzy Contrast Enhancement

Fuzzy Contrast Enhancement (FCE) is normally divided into three phases: image fuzzification, membership value modification, and image defuzzification. The robustness of the FCE system is in its second stage, as the contrast of the image is enhanced by transforming the membership values [12]. A visualization of the FCE is shown in Fig. 5.

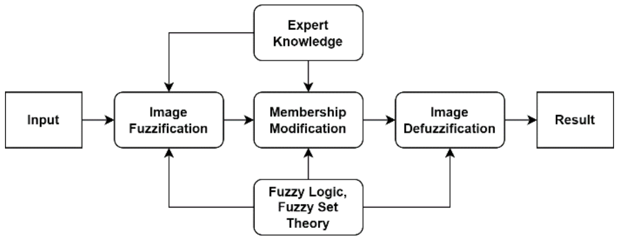


Fig. 5. FCE Visualization [12].

In this study we used 8 degrees of membership consisting of ED (ExtremelyDark), VD (VeryDark), Da (Dark), SD (SlightlyDark), SB (SlightlyBright), Br (Bright), VB (VeryBright), EB (ExtremelyBright). All membership degrees are set in pixel intensity by the Gaussian Function. The equation of the Gaussian Function is shown in (4).

$$G(x, c, \sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \quad (4)$$

The variable x is the pixel intensity value, c is the center value of the pixel intensity, e is the exponent, while σ defines the length of the membership degree.

All three image enhancement algorithms will be implemented on the same dataset and compared using evaluation metrics to find the best algorithm to increase immersiveness in virtual environments.

C. Evaluation Technique

The experimental process in this study uses five quantitative evaluation techniques to measure the performance of the proposed image enhancement algorithm. The first technique is the Structural Similarity Index (SSIM). This technique measures the level of similarity between the original image and the enhanced image. The higher the SSIM value, the lower the degradation level of the image information structure. The SSIM value range is from 0 to 1 [21]. The equation for this technique is shown in (5).

$$SSIM(x, y) = [l(x, y)]^{\alpha}[c(x, y)]^{\beta}\,[s(x, y)]^{\gamma} \quad (5)$$

Variable l (luminance) functions to compare brightness, c (contrast) functions to compare color intensity values, and s (structure) functions to compare brightness patterns. The x, y variables hold the pixel index values while the α, β, γ are constants with positive values. The second technique is Mean Squared Error (MSE). The technique is often used in the field of AI to calculate the difference between predicted and actual values. The equation of the MSE is shown in (6).

$$MSE = \frac{1}{M \times N} \sum_{i=0,\ j=0}^{M-1,\ N-1} [y'(i,j) - y(i,j)]^2 \quad (6)$$

M, N values are the length and width of the image, respectively. Meanwhile, y' is an enhanced image and y is an original image. Variables i, j represent the current pixel index position. The lower the MSE value, the better the quality of the enhanced image. The third technique is the Image Quality Index (IQI). This technique can produce measurements that represent a qualitative human perspective [10]. The equation of IQI is shown in (7).

$$IQI = \frac{4\sigma_{OM}\bar{A}_O\bar{A}_M}{(\sigma_O^2+\sigma_M^2)(\bar{A}_O^2+\bar{A}_M^2)} \quad (7)$$

The calculation of variance and covariance between the original image and the enhanced image will be a parameter to determine how similar the original image is to the processed image despite manipulation. $\bar{A}$ indicates the average gray scale value for the window pixels, σ^2 is the variance, and σ_{OM} is the covariance [22]. IQI considers performance good if it gets closer to 1. The fourth technique is Root Mean Squared Error (RMSE). This technique is a continuation of MSE by determining the root of the MSE value that has been obtained. The equation of the RMSE is shown in (8).

$$RMSE = \sqrt{MSE} \quad (8)$$

The fifth technique is Peak Signal-to-Noise Ratio (PSNR). This technique compares the maximum range of the signal from the image with the image noise obtained from the MSE. The higher the PSNR value, the better the performance of the image enhancement. The equation of the PSNR is shown in (9).

$$PSNR = 10 \times log_{10}[(Max^2)/MSE] \quad (9)$$

Based on the equation in (9), the MSE value is utilized by calculating it with Max which represents the maximum value of a pixel which is 255.

IV. Result and Discussion

The findings and discussion are presented in this section. The results of this experiment were assessed through both quantitative and qualitative perspectives. Through quantitative evaluation, five evaluation techniques were used. The results of the evaluation using the HE, CLAHE, and FCE methods are shown in Table. I, Table II, Table III respectively.

TABLE I. HE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,88	0,039	0,753	0,197	14,093
2.	1.png	0,874	0,032	0,789	0,179	14,926
3.	2.png	0,854	0,027	0,827	0,164	15,696
…	…	…	…	…	…	…
3157.	3156.png	0,835	0,032	0,691	0,18	14,916
Average		0,823	0,028	0,819	0,157	16,638

TABLE II. CLAHE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,972	0,003	0,975	0,052	25,656
2.	1.png	0,967	0,003	0,976	0,052	25,693
3.	2.png	0,957	0,004	0,969	0,06	24,4
…	…	…	…	…	…	…
3157.	1356.png	0,991	0,001	0,98	0,032	29,966
Average		0,959	0,003	0,959	0,055	25,705

TABLE III. FCE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,874	0,032	0,813	0,178	14,988
2.	1.png	0,855	0,032	0,81	0,178	15,004
3.	2.png	0,827	0,031	0,806	0,176	15,098
…	…	…	…	…	…	…
3157.	3156.png	0,981	0,005	0,955	0,070	23,112
Average		0,9	0,020	0,909	0,134	18,111

Referring to Table I, Table II, and Table III, evaluation is applied to all data. The original image data and the enhanced image are compared to provide value as a determining indicator of performance. Through an investigation process, the CLAHE Method was able to outperform the HE Method and FCE Method based on five evaluation parameters. In evaluating the level of similarity, namely SSIM and IQI, CLAHE excelled with an SSIM score of 0.959 and an IQI of 0.959. In measuring noise intensity, CLAHE again excels through MSE 0.003, RMSE 0.055, and PSNR 27.705. The comparison of the HE and CLAHE methods is visually shown in Fig. 5.

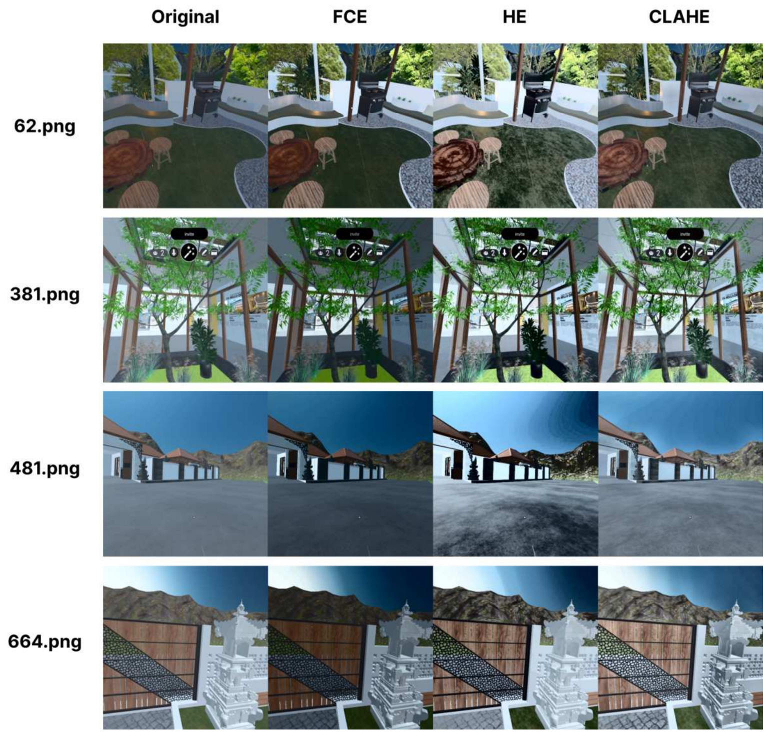


Fig. 6. Image Comparation.

Referring to Fig. 6, the level of visual image similarity between the original image and the enhanced image using CLAHE is in line with the measurement results using SSIM and IQI. The brightness level, color intensity, and pattern of brightness from CLAHE are close to the original image. This means that the information contained in the original image can be well preserved after going through the CLAHE method. This can be clarified by an example of histogram visualization on image 7.png shown in Fig. 7.

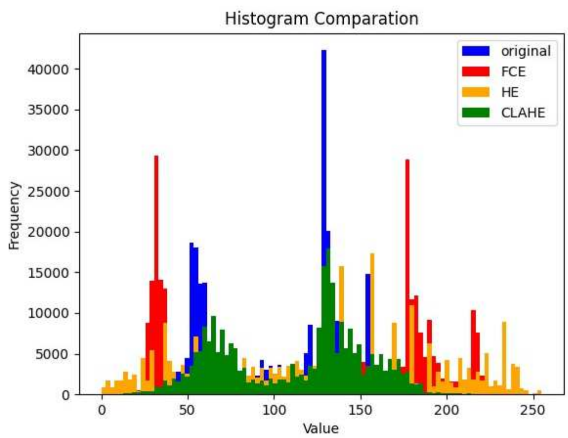


Fig. 7. Histogram Visualization.

Based on Fig. 7, the distribution of HE pixels tends to force all pixels to spread over the entire range of pixel values. The frequency distribution of the pixels is adopted by stretching over the entire range of pixel values. This causes over-enhancement. This deficiency can be corrected properly through the CLAHE method by applying the tiles generation parameter, which prevents global histogram equalization. The tile generation parameter is able to isolate the histogram equalization process so that the pixel distribution still follows the original image pattern without extreme stretching processes. This results in a contrast enhancement that can run while maintaining brightness [23]. The clip limit parameter also limits the excess frequency that can arise, so that object details can increase without over-enhancement.

Meanwhile, when referring to the FCE Histogram, the redistribution of pixel intensity is determined by the degree of membership. The membership degree comes from the Lightness histogram of the original image LAB color space. When referring to Fig. 7, the FCE redistribution still adapts the original image histogram by expanding the pixel values. However, the uneven distribution of pixel intensity results in the image having bright and dark pixel intensities clustered together or called over-contrast. Over-contrast occurs as a result of the membership degree transformation [12]. This results in the texture details of the 3D object being less visible.

In addition to measurements in the context of similarity, measuring the level of noise in the image enhancement results is also the focus of this research. CLAHE is able to produce lower MSE and RMSE values compared to HE and FCE. Referring to the image comparison visualization in Fig. 6 and the histogram visualization, it can be seen that the HE method experiences over-enhancement. The distribution of pixels with low and high values has a high frequency so that high noise becomes the weakness of the HE Method [19].The pixel intensity at high and low low pixel values that surges also occurs in FCE resulting in a noisy and unnatural image. The high noise value causes the PSNR measurement results in HE and FCE to be lower than CLAHE.

V. Conclusion

This experiment aims to improve the immersiveness of VR through the image enhancement method. The data used in this study amounted to 1.357 images in PNG format with a resolution of 512 x 512. We propose three image enhancement methods namely HE, CLAHE, and FCE to determine the method with the best performance. The stages of this research start from data finalization, image enhancement application, and evaluation. Through the investigation process, CLAHE method is able to outperform HE and FCE with an average of SSIM 0.959, IQI 0.959, through MSE 0.003, RMSE 0.055, and PSNR 25.705. The additional parameters of tiles generation and clip limit in CLAHE are able to improve the quality of VR environment image without causing over-enhancement. In future work, we will experiment the application of CLAHE Method to real VR Technology so as to improve the immersiveness of the VR environment.

References

[1] S. M. E. Sepasgozar, "Immersive on-the-job training module development and modeling users' behavior using parametric multi-group analysis: A modified educational technology acceptance model," *Technol. Soc.*, vol. 68, no. January, p. 101921, 2022, doi: 10.1016/j.techsoc.2022.101921.

[2] Z. Tacgin and B. Dalgarno, "Building an instructional design model for immersive virtual reality learning environments," *Des. Deploying, Eval. Virtual Augment. Real. Educ.*, pp. 20–47, 2020, doi: 10.4018/978-1-7998-5043-4.ch002.

[3] X. Fan, X. Jiang, and N. Deng, "Immersive technology: A meta-analysis of augmented/virtual reality applications and their impact on tourism experience," *Tour. Manag.*, vol. 91, no. 18, p. 104534, 2022, doi: 10.1016/j.tourman.2022.104534.

[4] S. Wu, H. Liu, Q. Xu, and Y. Liu, "Design and Research of Interactive Animation of Immersive Space Scene Based on Computer Vision Technology," *Math. Probl. Eng.*, vol. 2021, 2021, doi: 10.1155/2021/5554879.

[5] X. Chen *et al.*, "ImmerTai: Immersive Motion Learning in VR Environments," *J. Vis. Commun. Image Represent.*, vol. 58, pp. 416–427, 2019, doi: 10.1016/j.jvcir.2018.11.039.

[6] K. Stepan *et al.*, "Immersive virtual reality as a teaching tool for neuroanatomy," *Int. Forum Allergy Rhinol.*, vol. 7, no. 10, pp. 1006–1013, 2017, doi: 10.1002/alr.21986.

[7] S. Lontschar, D. Deegan, I. Humer, K. Pietroszek, and C. Eckhardt, "Analysis of Haptic Feedback and its Influences in Virtual Reality Learning Environments," *Proc. 6th Int. Conf. Immersive Learn. Res. Network, iLRN 2020*, no. iLRN, pp. 171–177, 2020, doi: 10.23919/iLRN47897.2020.9155087.

[8] B. I. Edwards, K. S. Bielawski, R. Prada, and A. D. Cheok, "Haptic virtual reality and immersive learning for enhanced organic chemistry instruction," *Virtual Real.*, vol. 23, no. 4, pp. 363–373, 2019, doi: 10.1007/s10055-018-0345-4.

[9] Y. M. Kim, Y. Lee, I. Rhiu, and M. H. Yun, "Evaluation of locomotion methods in virtual reality navigation environments: An involuntary position shift and task performance," *Int. J. Hum. Comput. Stud.*, vol. 155, no. July, p. 102691, 2021, doi: 10.1016/j.ijhcs.2021.102691.

[10] D. Asamoah, E. Ofori, S. Opoku, and J. Danso, "Measuring the Performance of Image Contrast Enhancement Technique," *Int. J. Comput. Appl.*, vol. 181, no. 22, pp. 6–13, 2018, doi: 10.5120/ijca2018917899.

[11] W. Nural, J. Hj, W. Yussof, M. Man, R. Umar, and A. N. Zulkeflee, "Enhancing Moon Crescent Visibility Using Contrast-Limited Adaptive Histogram Equalization and Bilateral Filtering Techniques," no. April, 2022, doi: 10.26636/jtit.2022.155721.

[12] P. Mittal, R. K. Saini, and N. K. Jain, *Image enhancement using fuzzy logic techniques*, vol. 742. Springer Singapore, 2019. doi: 10.1007/978-981-13-0589-4_50.

[13] S. Fernandes, H. Vashi, A. Shetty, and V. Kelkar, "Adaptive Contrast Enhancement using Fuzzy Logic," *2019 6th IEEE Int. Conf. Adv. Comput. Commun. Control. ICAC3 2019*, pp. 1–4, 2019, doi: 10.1109/ICAC347590.2019.9036770.

[14] K. Sui and W. H. Lee, "Image processing analysis and research based on game animation design," *J. Vis. Commun. Image Represent.*, vol. 60, no. December, pp. 94–100, 2019, doi: 10.1016/j.jvcir.2018.12.011.

[15] B. Liu, H. Liu, and V. P. Dung, "3D Animation Graphic Enhancing Process Effect Simulation Analysis," *Wirel. Commun. Mob. Comput.*, vol. 2022, 2022, doi: 10.1155/2022/9208495.

[16] D. D. R., "Improved Image Processing Techniques for User Immersion Problem Alleviation in Virtual Reality Environments," *J. Innov. Image Process.*, vol. 2, no. 2, pp. 77–84, 2020, doi: 10.36548/jiip.2020.2.002.

[17] J. Xu, "Immersive Display Design Based on Deep Learning Intelligent VR Technology," vol. 2022, 2022.

[18] P. J. Baldevbhai, "Color Image Segmentation for Medical Images using L*a*b* Color Space," *IOSR J. Electron. Commun. Eng.*, vol. 1, no. 2, pp. 24–45, 2012, doi: 10.9790/2834-0122445.

[19] L. Lu, Y. Zhou, K. Panetta, and S. Agaian, "Comparative study of histogram equalization algorithms for image enhancement," *Mob. Multimedia/Image Process. Secur. Appl. 2010*, vol. 7708, p. 770811, 2010, doi: 10.1117/12.853502.

[20] B. Oktavianto and T. W. Purboyo, "A Study of Histogram Equalization Techniques for Image Enhancement," *Int. J. Appl. Eng. Res.*, vol. 13, no. 2, pp. 1165–1170, 2018, [Online]. Available: http://www.ripublication.com

[21] U. Sara, M. Akter, and M. S. Uddin, "Image Quality Assessment through FSIM , SSIM , MSE and PSNR — A Comparative Study," pp. 8–18, 2019, doi: 10.4236/jcc.2019.73002.

[22] S. C. Lin, Y. C. Lin, W. S. Feng, J. M. Wu, and T. J. Chen, "A novel medical image quality index," *J. Digit. Imaging*, vol. 24, no. 5, pp. 874–882, 2011, doi: 10.1007/s10278-010-9353-y.

[23] M. Kumar and A. Rana, "Image Enhancement using Contrast Limited Adaptive Histogram Equalization and Wiener filter," *Int. J. Eng. Comput. Sci.*, vol. 5, no. 16977, pp. 16977–16979, 2016, doi: 10.18535/ijecs/v5i6.30.

Image Enhancement

by Artikel Enhancement

Submission date: 13-Sep-2023 02:25PM (UTC+0700)
Submission ID: 2164864690
File name: a37-sindu_final.pdf (730.16K)
Word count: 4331
Character count: 21824

Improved Immersive Virtual Reality (VR) using Image Enhancement Method

I Gede Partha Sindu
Dept. of Informatics
Universitas Pendidikan Ganesha
Singaraja, Bali, Indonesia
partha.sindu@undiksha.ac.id

Rukmi Sari Hartati
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
rukmisari@unud.ac.id

Made Sudarma
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
msudarma@unud.ac.id

Nyoman Gunantara
Faculty Of Engineering
Universitas Udayana
Denpasar, Bali, Indonesia
gunantara@unud.ac.id

***Abstract*—The research aims to enhance immersive VR through improved design display quality in virtual environments. It is grounded in the image problem because in the virtual environment, there is a difference in color contrast 3D design interior and exterior environments of residential with a real view of the interior and external environments of buildings. So the results of the design of the interior and exterior environments of housing are still not immersive and do not look natural or real. The method used is image enhancement consisting of Histogram Enhancement (HE), Contrast-Limited Adaptive Histogram (CLAHE), and Fuzzy Contrast Enhancement (FCE). The data used in this study totaled 3.157 images in PNG format with a resolution of 512 x 512. The stages of this study start with data finalization, the image enhancement process, and evaluation. Through the investigative process, CLAHE method is able to outperform HE and FCE with an average of Structural Similarity Index (SSIM) 0.959, Image Quality Index (IQI) 0.959, through Mean Squared Error (MSE) 0.003, Root Mean Squared Error (RMSE) 0.055, and Peak Signal-to-Noise Ratio (PSNR) 25.705. Additional parameters, such as tiles generation and clip limit, on CLAHE can improve the image quality of the virtual environment without causing over-enhancement.**

Keywords*— *Immersive VR, Image Enhancement, HE, CLAHE

I. Introduction

Virtual Reality (VR) is a technology that has the benefit of providing in-depth knowledge and experiences to its users [1]. The main advantage of VR is the experience that makes users feel the sensations of the real world in the virtual world [2], [3]. With VR, the user is brought to another dimension whose state depiction resembles the original shape of the object, while the reality is that the user remains in the same place. One of the key elements of the VR environment is immersion [4]. Immersion in the virtual environment is a technology where the entire walls and floors of a room are projected with moving images that are equipped with sound so that visitors can experience a unique and exciting experience [5]. These moving images should be designed to resemble the original as seen in the real world. So the perception of physical presence in the virtual environment becomes increasingly real. The application of VR immersive has been widely used in various fields of education, engineering, science, medicine, and others [6]–[9].

The application of VR in the field of education, especially in the study and making of 3D design, still encounters some barriers, especially from the side of making the color texture image design of the virtual environment look real and natural. In the process of creating 3D textures using the applications Blender and Sketchup. However, the results have not yet been able to make the interior and exterior design of the home look real and natural. So a method is needed to improve the quality of the 3D texturing. The application used to display the results of this 3D texturing design uses the Mozilla Hubs platform. The Mozilla Hubs platform is able to display 3D design results using virtual reality tools. The VR tool is called Oqulus Quest 2.

At the stage of creation, VR has a complex flow and needs. Before moving to the Mozilla Hubs platform, the 3D asset created must go through a process of minimizing 3D file size to optimize the performance of VR technology on Mozilla Hubs. In the first step of research, we have already modeled the interior and exterior environments of resedential using Sketchup. The next step is to fix abnormalities in the Sketchup modeling process using Blender. The development carried out needs to pay attention to the use of material units such as vegetation, landscape, plants, furniture, and texture. The material units used have been selected and re-adjusted to have a small file size without reducing the color appearance of the interior and exterior environment designs. The image problem in the virtual environment is a difference in color contrast 3D design interior and exterior environment of residential with a real view of the interior and external environment of the residential. This causes the results of residential interior and exterior environment design images to still not be immersive and do not look natural so it is necessary to improve image quality in the virtual environment. Through the image enhancement approach, each frame of the virtual environment will be processed using Image Enhancement Algorithms including HE, CLAHE, and FCE. Each of these image enhancement algorithms will be compared to produce the best image enhancement algorithm to increase immersion in the virtual environment.

In the next section, we present research related to Part II. In Part III, we present the stages of this research. In Part IV, we present the findings and discussions, and last in Part V we deliver the conclusions and subsequent work.

II. Related Works

There are several previous studies that investigated image quality improvement and enhancement. Dominic et al. [10] conducted image enhancement experiments with the goal of extracting hidden information from images in their paper. The methods in this paper include HE, Adaptive Histogram Equalization (AHE), and CLAHE which are applied to dark images with lots of noise. Through the results of the investigation, the best enhancement results were obtained in the HE method, with an IQI of 68% and a SI of 31%. The use of the CLAHE method was also proposed by Yussof et al. [11] in their research by combining it with Bilateral Filtering to increase the contrast of the crescent moon image. This study demonstrated the ability of CLAHE and Bilateral Filtering to increase contrast with a PSNR value of 66.48% and an MSE of 0.01. The FCE method is also utilized in the case of image enhancement as proposed by Mittal et al. [12] with an in-depth discussion of FCE to improve image quality. Samrudh et al. [13] in their experiments showed that the FCE method is able to outperform the HE method using the PSNR evaluation.

In addition to improving the quality of digital images of real objects, quality improvements have also led to 3D objects. Sui et al. [14] in their study applied image enhancement to game animation designs. Through the Q-Learning method, the scene display in the game becomes more comfortable to look at and looks natural. The application of image enhancement to 3D animation was also proposed by Liu et al. [15]. Through the proposed algorithm, the highest PSNR is 72.88%. and the MSE is 0.362. Whereas in VR, image enhancement is also implemented to improve display quality. Dhaya [16] proposed Multi Scale Retinex (MSR) with an average percentage of image quality of 88.8% and an error of 0.018. Jing Xu [17] proposed a deep learning method to predict each pixel of the VR display so as to give an impression. Through the questionnaires distributed, it was found that 83% of the users were very satisfied with the VR display using this method, and 16% were quite satisfied.

III. Methods

In this section, there are a series of steps that are taken to investigate the capabilities of the proposed method. The stages in this study consisted of data finalization, application of the image enhancement algorithm, and evaluation stages. The details of a series of stages are presented in the following sub-sections:

A. Data

The main data in this study was personally acquired from VR video recordings with residential interior and exterior environments. The videos were MP4 format with 1024 x 1024 resolution and 25 FPS. There are 6 videos with each duration, namely: Video 1 (4:14), Video 2 (3:50), Video 3 (5:21), Video 4 (3:03), Video 5 (2:54), Video 6 (11:15). All videos have RGB color depth. The acquired videos are shown in Fig. 1. While The details of the preprocessing stages are shown in Fig. 2.

Fig. 1. Example of data acquisition results.

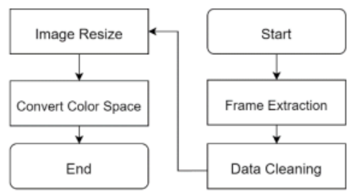


Fig. 2. Visualization of Preprocessing Stages.

Referring to Fig. 1, Each video was shot in a different place showing both the interior and exterior components of the building.

As shown in Fig. 2, each video is extracted by taking only 5 frames out of 25 frames in one second. Frame extraction resulted in 3.184 images. It then goes through data cleaning to eliminate unnecessary data. The total number of final images used is 3.157. Image resize is applied to reduce the computational load. The image is resized to 512 x 512 RGB channels. All images were then converted into LAB channels. LAB stands for L (Lightness), A (red-green color), B (yellow-blue color). This color space format is needed because the HE, CLAHE, and FCE processes require the L (Lightness) channel which is the intensity level of lightness. The L channel is made as similar as possible to the human perception of illumination [18].

B. Image Enhancement Algorithm

The image enhancement proposed in this paper consists of the HE, CLAHE, and FCE Algorithm. As for the details of each algorithm proposed in this study, as follows:

1) Histogram Equalization

Histogram Equalization (HE) is an image processing algorithm to improve image quality through an even distribution of pixel intensity so that the contrast of the image increases. The equation of HE that describes the probability of pixel i is shown in (1).

$$p_x(i) = \frac{n_i}{n}, 0 \leq i \leq L \quad (1)$$

The n_i value is the number of pixels with an intensity value, while n is the number of pixels. The value of the i intensity can be from 0 to less than L, which is the highest intensity level of 256. The value of i needs to be normalized so that it produces a value of [0, 1]. The normalization process is based on the Cumulative Probability Function (CDF) so that the intensity of all pixels is normalized [19], The equation of the CDF is shown in (2).

$$CDF(i) = \sum_{j=0}^{i} P_x(j) \quad (2)$$

In order for normalized intensity values to be visualized, the final equation shown in (3) is needed.

$$S(i) = (L-1) \times CDF(i) \quad (3)$$

$S(i)$ or the i sequence holds the value of the calculation of each pixel sequence so that a new pixel intensity distribution is formed. The visualization of the image level intensity distribution comparison after going through the HE process is shown in Fig. 3.

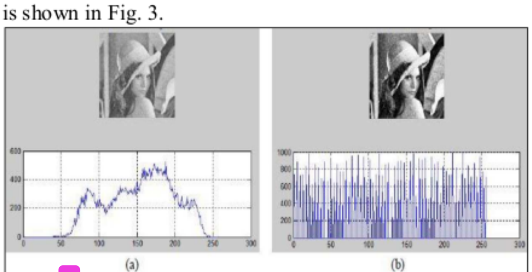


Fig. 3. Comparison between (a) the original image and (b) the image with HE [20].

Referring to Fig. 3, it can be seen that the pixel intensity is stretched so that it is evenly distributed throughout the intensity so that the contrast of the image can increase.

2) Contrast-Limited Adaptive Histogram

HE will be compared with CLAHE and FCE to find the best Image Enhancement algorithm. CLAHE was initiated to overcome the drawback of HE, which forces the distribution of pixel intensity to be equal. This results in excess contrast at both high and low intensity levels. The CLAHE process is visually shown in Fig. 4.

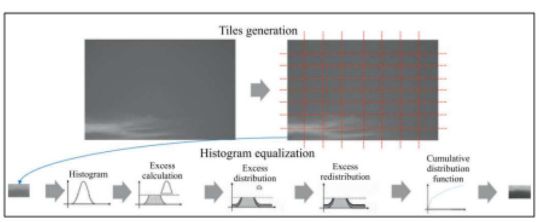


Fig. 4. CLAHE Visualization [11].

Based on Fig. 4, there are two main parts to the CLAHE process. The Tiles generation stage involves dividing the image into 16 separate parts. The 16 separate parts are obtained from the dividing parameter, which is 8 x 8. This stage serves to isolate the HE processes so they don't run on the global image. The next stage is HE on each part of the image and the clip limit parameter. The Clip parameter in the HE process is able to limit excess contrast in the pixel intensity distribution. The clip parameter used is 2.0.

3) Fuzzy Contrast Enhancement

Fuzzy Contrast Enhancement (FCE) is normally divided into three phases: image fuzzification, membership value modification, and image defuzzification. The robustness of the FCE system is in its second stage, as the contrast of the image is enhanced by transforming the membership values [12]. A visualization of the FCE is shown in Fig. 5.

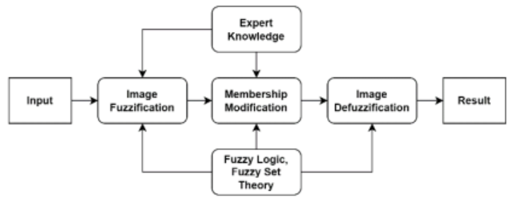


Fig. 5. FCE Visualization [12].

In this study we used 8 degrees of membership consisting of ED (ExtremelyDark), VD (VeryDark), Da (Dark), SD (SlightlyDark), SB (SlightlyBright), Br (Bright), VB (VeryBright), EB (ExtremelyBright). All membership degrees are set in pixel intensity by the Gaussian Function. The equation of the Gaussian Function is shown in (4).

$$G(x, c, \sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \quad (4)$$

The variable x is the pixel intensity value, c is the center value of the pixel intensity, e is the exponent, while σ defines the length of the membership degree.

All three image enhancement algorithms will be implemented on the same dataset and compared using evaluation metrics to find the best algorithm to increase immersiveness in virtual environments.

C. Evaluation Technique

The experimental process in this study uses five quantitative evaluation techniques to measure the performance of the proposed image enhancement algorithm. The first technique is the Structural Similarity Index (SSIM). This technique measures the level of similarity between the original image and the enhanced image. The higher the SSIM value, the lower the degradation level of the image information structure. The SSIM value range is from 0 to 1 [21]. The equation for this technique is shown in (5).

$$SSIM(x, y) = [l(x, y)]^{\alpha}[c(x, y)]^{\beta}\,[s(x, y)]^{\gamma} \quad (5)$$

Variable l (luminance) functions to compare brightness, c (contrast) functions to compare color intensity values, and s (structure) functions to compare brightness patterns. The x, y variables hold the pixel index values while the α, β, γ are constants with positive values. The second technique is Mean Squared Error (MSE). The technique is often used in the field of AI to calculate the difference between predicted and actual values. The equation of the MSE is shown in (6).

$$MSE = \frac{1}{M \times N} \sum_{i=0,\ j=0}^{M-1,\ N-1} [y'(i,j) - y(i,j)]^2 \quad (6)$$

M, N values are the length and width of the image, respectively. Meanwhile, y' is an enhanced image and y is an original image. Variables i, j represent the current pixel index position. The lower the MSE value, the better the quality of the enhanced image. The third technique is the Image Quality Index (IQI). This technique can produce measurements that represent a qualitative human perspective [10]. The equation of IQI is shown in (7).

$$IQI = \frac{4\sigma_{OM}\bar{A}_O\bar{A}_M}{(\sigma_O^2+\sigma_M^2)(\bar{A}_O^2+\bar{A}_M^2)} \quad (7)$$

The calculation of variance and covariance between the original image and the enhanced image will be a parameter to determine how similar the original image is to the processed image despite manipulation. $\bar{A}$ indicates the average gray scale value for the window pixels, σ^2 is the variance, and σ_{OM} is the covariance [22]. IQI considers performance good if it gets closer to 1. The fourth technique is Root Mean Squared Error (RMSE). This technique is a continuation of MSE by determining the root of the MSE value that has been obtained. The equation of the RMSE is shown in (8).

$$RMSE = \sqrt{MSE} \quad (8)$$

The fifth technique is Peak Signal-to-Noise Ratio (PSNR). This technique compares the maximum range of the signal from the image with the image noise obtained from the MSE. The higher the PSNR value, the better the performance of the image enhancement. The equation of the PSNR is shown in (9).

$$PSNR = 10 \times log_{10}[(Max^2)/MSE] \quad (9)$$

Based on the equation in (9), the MSE value is utilized by calculating it with Max which represents the maximum value of a pixel which is 255.

IV. Result and Discussion

The findings and discussion are presented in this section. The results of this experiment were assessed through both quantitative and qualitative perspectives. Through quantitative evaluation, five evaluation techniques were used. The results of the evaluation using the HE, CLAHE, and FCE methods are shown in Table. I, Table II, Table III respectively.

TABLE I. HE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,88	0,039	0,753	0,197	14,093
2.	1.png	0,874	0,032	0,789	0,179	14,926
3.	2.png	0,854	0,027	0,827	0,164	15,696
…	…	…	…	…	…	…
3157.	3156.png	0,835	0,032	0,691	0,18	14,916
Average		0,823	0,028	0,819	0,157	16,638

TABLE II. CLAHE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,972	0,003	0,975	0,052	25,656
2.	1.png	0,967	0,003	0,976	0,052	25,693
3.	2.png	0,957	0,004	0,969	0,06	24,4
…	…	…	…	…	…	…
3157.	1356.png	0,991	0,001	0,98	0,032	29,966
Average		0,959	0,003	0,959	0,055	25,705

TABLE III. FCE Evaluation Result

ID	Image	SSIM	MSE	IQI	RMSE	PSNR
1.	0.png	0,874	0,032	0,813	0,178	14,988
2.	1.png	0,855	0,032	0,81	0,178	15,004
3.	2.png	0,827	0,031	0,806	0,176	15,098
…	…	…	…	…	…	…
3157.	3156.png	0,981	0,005	0,955	0,070	23,112
Average		0,9	0,020	0,909	0,134	18,111

Referring to Table I, Table II, and Table III, evaluation is applied to all data. The original image data and the enhanced image are compared to provide value as a determining indicator of performance. Through an investigation process, the CLAHE Method was able to outperform the HE Method and FCE Method based on five evaluation parameters. In evaluating the level of similarity, namely SSIM and IQI, CLAHE excelled with an SSIM score of 0.959 and an IQI of 0.959. In measuring noise intensity, CLAHE again excels through MSE 0.003, RMSE 0.055, and PSNR 27.705. The comparison of the HE and CLAHE methods is visually shown in Fig. 5.

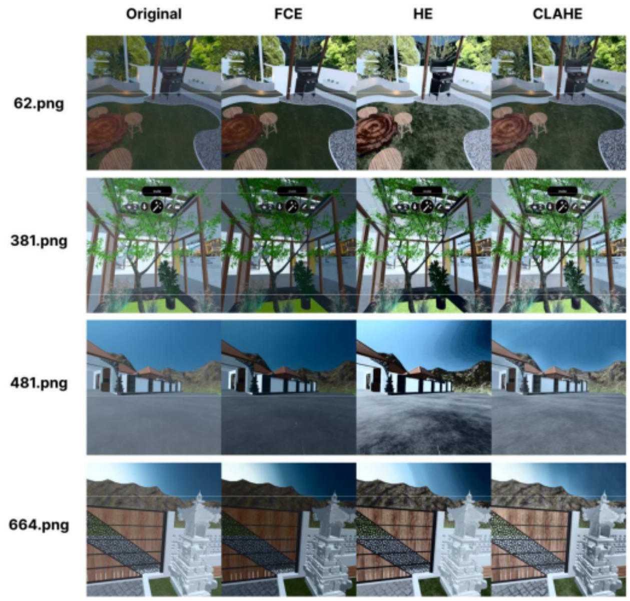


Fig. 6. Image Comparation.

Referring to Fig. 6, the level of visual image similarity between the original image and the enhanced image using CLAHE is in line with the measurement results using SSIM and IQI. The brightness level, color intensity, and pattern of brightness from CLAHE are close to the original image. This means that the information contained in the original image can be well preserved after going through the CLAHE method. This can be clarified by an example of histogram visualization on image 7.png shown in Fig. 7.

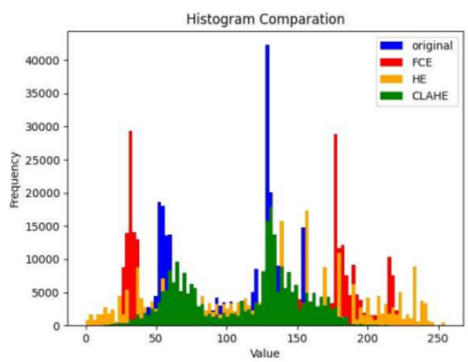


Fig. 7. Histogram Visualization.

Based on Fig. 7, the distribution of HE pixels tends to force all pixels to spread over the entire range of pixel values. The frequency distribution of the pixels is adopted by stretching over the entire range of pixel values. This causes over-enhancement. This deficiency can be corrected properly through the CLAHE method by applying the tiles generation parameter, which prevents global histogram equalization. The tile generation parameter is able to isolate the histogram equalization process so that the pixel distribution still follows the original image pattern without extreme stretching processes. This results in a contrast enhancement that can run while maintaining brightness [23]. The clip limit parameter also limits the excess frequency that can arise, so that object details can increase without over-enhancement.

Meanwhile, when referring to the FCE Histogram, the redistribution of pixel intensity is determined by the degree of membership. The membership degree comes from the Lightness histogram of the original image LAB color space. When referring to Fig. 7, the FCE redistribution still adapts the original image histogram by expanding the pixel values. However, the uneven distribution of pixel intensity results in the image having bright and dark pixel intensities clustered together or called over-contrast. Over-contrast occurs as a result of the membership degree transformation [12]. This results in the texture details of the 3D object being less visible.

In addition to measurements in the context of similarity, measuring the level of noise in the image enhancement results is also the focus of this research. CLAHE is able to produce lower MSE and RMSE values compared to HE and FCE. Referring to the image comparison visualization in Fig. 6 and the histogram visualization, it can be seen that the HE method experiences over-enhancement. The distribution of pixels with low and high values has a high frequency so that high noise becomes the weakness of the HE Method [19]. The pixel intensity at high and low low pixel values that surges also occurs in FCE resulting in a noisy and unnatural image. The high noise value causes the PSNR measurement results in HE and FCE to be lower than CLAHE.

V. Conclusion

This experiment aims to improve the immersiveness of VR through the image enhancement method. The data used in this study amounted to 1.357 images in PNG format with a resolution of 512 x 512. We propose three image enhancement methods namely HE, CLAHE, and FCE to determine the method with the best performance. The stages of this research start from data finalization, image enhancement application, and evaluation. Through the investigation process, CLAHE method is able to outperform HE and FCE with an average of SSIM 0.959, IQI 0.959, through MSE 0.003, RMSE 0.055, and PSNR 25.705. The additional parameters of tiles generation and clip limit in CLAHE are able to improve the quality of VR environment image without causing over-enhancement. In future work, we will experiment the application of CLAHE Method to real VR Technology so as to improve the immersiveness of the VR environment.

References

[1] S. M. E. Sepasgozar, "Immersive on-the-job training module development and modeling users' behavior using parametric multi-group analysis: A modified educational technology acceptance model," *Technol. Soc.*, vol. 68, no. January, p. 101921, 2022, doi: 10.1016/j.techsoc.2022.101921.

[2] Z. Tacgin and B. Dalgarno, "Building an instructional design model for immersive virtual reality learning environments," *Des. Deploying, Eval. Virtual Augment. Real. Educ.*, pp. 20–47, 2020, doi: 10.4018/978-1-7998-5043-4.ch002.

[3] X. Fan, X. Jiang, and N. Deng, "Immersive technology: A meta-analysis of augmented/virtual reality applications and their impact on tourism experience," *Tour. Manag.*, vol. 91, no. 18, p. 104534, 2022, doi: 10.1016/j.tourman.2022.104534.

[4] S. Wu, H. Liu, Q. Xu, and Y. Liu, "Design and Research of Interactive Animation of Immersive Space Scene Based on Computer Vision Technology," *Math. Probl. Eng.*, vol. 2021, 2021, doi: 10.1155/2021/5554879.

[5] X. Chen *et al.*, "ImmerTai: Immersive Motion Learning in VR Environments," *J. Vis. Commun. Image Represent.*, vol. 58, pp. 416–427, 2019, doi: 10.1016/j.jvcir.2018.11.039.

[6] K. Stepan *et al.*, "Immersive virtual reality as a teaching tool for neuroanatomy," *Int. Forum Allergy Rhinol.*, vol. 7, no. 10, pp. 1006–1013, 2017, doi: 10.1002/alr.21986.

[7] S. Lontschar, D. Deegan, I. Humer, K. Pietroszek, and C. Eckhardt, "Analysis of Haptic Feedback and its Influences in Virtual Reality Learning Environments," *Proc. 6th Int. Conf. Immersive Learn. Res. Network, iLRN 2020*, no. iLRN, pp. 171–177, 2020, doi: 10.23919/iLRN47897.2020.9155087.

[8] B. I. Edwards, K. S. Bielawski, R. Prada, and A. D. Cheok, "Haptic virtual reality and immersive learning for enhanced organic chemistry instruction," *Virtual Real.*, vol. 23, no. 4, pp. 363–373, 2019, doi: 10.1007/s10055-018-0345-4.

[9] Y. M. Kim, Y. Lee, I. Rhiu, and M. H. Yun, "Evaluation of locomotion methods in virtual reality navigation environments: An involuntary position shift and task performance," *Int. J. Hum. Comput. Stud.*, vol. 155, no. July, p. 102691, 2021, doi: 10.1016/j.ijhcs.2021.102691.

[10] D. Asamoah, E. Ofori, S. Opoku, and J. Danso, "Measuring the Performance of Image Contrast Enhancement Technique," *Int. J. Comput. Appl.*, vol. 181, no. 22, pp. 6–13, 2018, doi: 10.5120/ijca2018917899.

[11] W. Nural, J. Hj, W. Yussof, M. Man, R. Umar, and A. N. Zulkeflee, "Enhancing Moon Crescent Visibility Using Contrast-Limited Adaptive Histogram Equalization and Bilateral Filtering Techniques," no. April, 2022, doi: 10.26636/jtit.2022.155721.

[12] P. Mittal, R. K. Saini, and N. K. Jain, *Image enhancement using fuzzy logic techniques*, vol. 742. Springer Singapore, 2019. doi: 10.1007/978-981-13-0589-4_50.

[13] S. Fernandes, H. Vashi, A. Shetty, and V. Kelkar, "Adaptive Contrast Enhancement using Fuzzy Logic," *2019 6th IEEE Int. Conf. Adv. Comput. Commun. Control. ICAC3 2019*, pp. 1–4, 2019, doi: 10.1109/ICAC347590.2019.9036770.

[14] K. Sui and W. H. Lee, "Image processing analysis and research based on game animation design," *J. Vis. Commun. Image Represent.*, vol. 60, no. December, pp. 94–100, 2019, doi: 10.1016/j.jvcir.2018.12.011.

[15] B. Liu, H. Liu, and V. P. Dung, "3D Animation Graphic Enhancing Process Effect Simulation Analysis," *Wirel. Commun. Mob. Comput.*, vol. 2022, 2022, doi: 10.1155/2022/9208495.

[16] D. D. R., "Improved Image Processing Techniques for User Immersion Problem Alleviation in Virtual Reality Environments," *J. Innov. Image Process.*, vol. 2, no. 2, pp. 77–84, 2020, doi: 10.36548/jiip.2020.2.002.

[17] J. Xu, "Immersive Display Design Based on Deep Learning Intelligent VR Technology," vol. 2022, 2022.

[18] P. J. Baldevbhai, "Color Image Segmentation for Medical Images using L*a*b* Color Space," *IOSR J. Electron. Commun. Eng.*, vol. 1, no. 2, pp. 24–45, 2012, doi: 10.9790/2834-0122445.

[19] L. Lu, Y. Zhou, K. Panetta, and S. Agaian, "Comparative study of histogram equalization algorithms for image enhancement," *Mob. Multimedia/Image Process. Secur. Appl. 2010*, vol. 7708, p. 770811, 2010, doi: 10.1117/12.853502.

[20] B. Oktavianto and T. W. Purboyo, "A Study of Histogram Equalization Techniques for Image Enhancement," *Int. J. Appl. Eng. Res.*, vol. 13, no. 2, pp. 1165–1170, 2018, [Online]. Available: http://www.ripublication.com

[21] U. Sara, M. Akter, and M. S. Uddin, "Image Quality Assessment through FSIM , SSIM , MSE and PSNR — A Comparative Study," pp. 8–18, 2019, doi: 10.4236/jcc.2019.73002.

[22] S. C. Lin, Y. C. Lin, W. S. Feng, J. M. Wu, and T. J. Chen, "A novel medical image quality index," *J. Digit. Imaging*, vol. 24, no. 5, pp. 874–882, 2011, doi: 10.1007/s10278-010-9353-y.

[23] M. Kumar and A. Rana, "Image Enhancement using Contrast Limited Adaptive Histogram Equalization and Wiener filter," *Int. J. Eng. Comput. Sci.*, vol. 5, no. 16977, pp. 16977–16979, 2016, doi: 10.18535/ijecs/v5i6.30.

Image Enhancement

ORIGINALITY REPORT

10%	5%	9%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.ncbi.nlm.nih.gov Internet Source	1%
2	escholarship.org Internet Source	1%
3	Yafeng Li, Ju Liu, Xiaoxi Liu, Xuejing Wang, Xuesong Gao, Yuyi Zhang. "HCISNet: Higher-capacity invisible image steganographic network", IET Image Processing, 2021 Publication	1%
4	Sam Devavaram Jebaraj, Srinidhi N. "JPEG-XL based Compression of DICOM Images for Reduced Storage and Transmission Costs", 2023 3rd International Conference on Intelligent Technologies (CONIT), 2023 Publication	1%
5	Gede Eka Cahyadi, Gede Sukadarmika, Yoga Divayana, Nyoman Putra Sastra. "Determination of Effective Radio Frequency Monitoring Locations Using Fuzzy-Analytical Hierarchy Process", 2021 International Conference on Smart-Green Technology in	<1%

Electrical and Information Systems (ICSGTEIS), 2021
Publication

6	link.springer.com Internet Source	<1 %
7	"Advances in Visual Computing", Springer Science and Business Media LLC, 2022 Publication	<1 %
8	A.N. Zulkeflee, W.N.J. Wan Yussof, R. Umar, N. Ahmad, F.S. Mohamad, M. Man, E.A. Awalludin. "Detection of a new crescent moon using the Maximally Stable Extremal Regions (MSER) technique", Astronomy and Computing, 2022 Publication	<1 %
9	"Second International Conference on Image Processing and Capsule Networks", Springer Science and Business Media LLC, 2022 Publication	<1 %
10	"Virtual, Augmented and Mixed Reality. Industrial and Everyday Life Applications", Springer Science and Business Media LLC, 2020 Publication	<1 %
11	Gede Sukadarmika, Rukmi Sari Hartati, Linawati, Nyoman Putra Sastra. "Introducing TAMEx model for availability of e-exam in	<1 %

wireless environment", 2018 International Conference on Information and Communications Technology (ICOIACT), 2018
Publication

12	"Intelligent Computing Applications for Sustainable Real-World Systems", Springer Science and Business Media LLC, 2020 Publication	<1%
13	Submitted to Universiti Teknologi Malaysia Student Paper	<1%
14	www.coursehero.com Internet Source	<1%
15	Submitted to University College London Student Paper	<1%
16	doaj.org Internet Source	<1%
17	scholar.ufs.ac.za Internet Source	<1%
18	Hope Orovwode, Ibukun Deborah Oduntan, John Abubakar. "Development of a Sign Language Recognition System Using Machine Learning", 2023 International Conference on Artificial Intelligence, Big Data, Computing and Data Communication Systems (icABCD), 2023 Publication	<1%

19	Zobeda Hatif Naji AL-Azzawi, Wisam Hayder Mahdi, Shaimaa Khamees Ahmed, Waqas Saad Yasin. "Medical image enhancement using histogram equalization techniques", AIP Publishing, 2023 Publication	<1%
20	imagelab.stu.edu.cn Internet Source	<1%
21	Ngaiming Kwok, Haiyan Shi. "Design of unsharp masking filter kernel and gain using particle swarm optimization", 2014 7th International Congress on Image and Signal Processing, 2014 Publication	<1%
22	P Sankalprajan, Thrilochan Sharma, Hamsa Datta Perur, Prithvi Sekhar Pagala. "Comparative analysis of ROS based 2D and 3D SLAM algorithms for Autonomous Ground Vehicles", 2020 International Conference for Emerging Technology (INCET), 2020 Publication	<1%
23	digitalcommons.usu.edu Internet Source	<1%
24	ejournal.undiksha.ac.id Internet Source	<1%
25	ijeecs.iaescore.com Internet Source	<1%

26	Shahan C. Nercessian, Karen A. Panetta, Sos. S. Agaian. "Non-Linear Direct Multi-Scale Image Enhancement Based on the Luminance and Contrast Masking Characteristics of the Human Visual System", IEEE Transactions on Image Processing, 2013 Publication	<1%
27	A.A. Gede Yudhi Paramartha, I Gede Partha Sindu, Kadek Yota Ernanda Aryanto. "Applying open content concept by synchronizing lecture video and slide", 2016 International Conference on Informatics and Computing (ICIC), 2016 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		

Certificate of Presentation
Presented to

I Gede Partha Sindu; Rukmi Sari Hartati; Made Sudarma; Nyoman Gunantara

For the paper

**Improved Immersive Virtual Reality (VR)
Using ImageEnhancement Method**

The 10th International Conference On
Information Technology, Computer And
Electrical Engineering

31st August - 1st September, 2023
Semarang - Indonesia

Dr. Rinta Kridalukmana
General Chair of ICITACEE 2023