AIP Conference Proceedings

AIP Publishing

Volume 3077

# Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

## Development of Digital and Green Technology on Post Pandemic Era

**Yogyakarta, Indonesia** • 21 September 2022

**Editors** • Ade Gafar Abdullah, Desi Ramayanti, Henri Septanto and Yohanes Galih Adhiyoga

TSET 2022

Available Online: pubs.aip.org/aip/acp

RESEARCH ARTICLE | JULY 12 2024

# Preface: Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

*AIP Conf. Proc.* 3077, 010001 (2024)
https://doi.org/10.1063/12.0024850

# PREFACE: Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

***"Development of Digital and Green Technology on Post Pandemic Era"***

It is with great pleasure to welcome you to Transdisciplinary Symposium on Engineering and Technology (TSET) 2022 hosted by Universitas Dian Nusantara on September 21, 2022. The event aims to a venue for engineers, researchers, scholars, and policy makers to explore the challenges and opportunities from the post pandemic era on civil engineering, mechanical engineering, electrical engineering and computer science. For civil engineers, they will play a significant part in the recovery since design and construction services will be needed in the future, and they need to develop new construction methods, materials, and technologies in order to build a sustainable and resilient infrastructure. For engineers, they need to start thinking about the long-term change of their operations and adapt to the "new normal" that has emerged because of the epidemic. We welcome all parties to share their research and thoughts in the symposium.

Participants of the symposium were invited to submit their papers and disseminate them through oral presentation covering such scope as civil engineering, mechanical engineering, electrical engineering and computer science. To enrich the discussion under the theme of "Development of Digital and Green Technology on Post Pandemic Era", we invited speakers with reputable expertise, namely Prof. Josaphat Tetuko Sri Sumantyo, Ph.D. from Chiba University, Japan; Prof. Dr. rer. nat. Evvy Kartini, M.Sc. from National Nuclear Energy Agency of Indonesia; Prof. Dr. Ir. Bambang Sugiarto,, M.Eng. from Universitas Indonesia, Indonesia; and Sulfikar Amir, Ph.D. from Nanyang Technological University, Singapore. In addition to presenting their research results, the participants of the symposium were also encouraged to submit their papers to be proposed for publication to American Institute of Physics (AIP), one of the world's top publishers as conference proceedings. There were 125 manuscripts submitted to the committee comprising 99 papers of Biology, Chemistry, Computer Science and Technology, and Engineering.

Finally, on behalf of the editors of TSET 2022, I would like to extend my most sincere gratitude to the organizing committee, co-hosting institutions, and most importantly, participants, speakers, presenters, and authors of the symposium. I do hope the proceedings bring significant contribution, particularly to the field of advances of sustainable engineering. I look forward to seeing you all at the upcoming symposium.

The Editors,
Ade Gafar Abdullah
Desi Ramayanti
Henri Septanto
Yohanes Galih Adhiyoga



*Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022*
AIP Conf. Proc. 3077, 010001-1–010001-1; https://doi.org/10.1063/12.0024850
Published under an exclusive license by AIP Publishing. 978-0-7354-4964-0/$30.00

RESEARCH ARTICLE | JULY 12 2024

# Committees: Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

*AIP Conf. Proc.* 3077, 010002 (2024)
https://doi.org/10.1063/12.0026137

# TSET 2022 COMMITTEE

**Advisory Board**
Prof. Josaphat Tetuko Sri Sumantyo
Prof. Sulfikar Amir
Prof. E.S. Margianti
Prof. Bambang Sugiarto
Prof. Raihan
Prof. Moermahadi Soerja Djanegara
Prof. Evvy Kartini
Prof. Memen Kustiawan
Prof. Jony Oktavianto
Prof. Intiyas Utami
Dr. Awaludin Martin

**Scientific Committee**
Prof. Ade Gafar Abdullah
Prof. Suharyadi
Dr. M. Hasannudin Toyieb
Dr. Dewi Anggraini
Magito

**Organizing Committee**
**Conference Chair:**
Ir. Margono Sugeng, M.Sc.

**Co-Conference Chair:**
Ir. Komarudin, ST., MT

**Members:**
Assoc. Prof. Isma Widiaty
Dr. Yohanes Galih Adhiyoga
Dr. Ari Purwanti
Dr. Didin Hikmah Perkasa
Kornelia Johana, S.I.Kom., M.I.Kom



*Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022*
AIP Conf. Proc. 3077, 010002-1–010002-1; https://doi.org/10.1063/12.0026137
Published under an exclusive license by AIP Publishing. 978-0-7354-4964-0/$30.00

# Issues

Select Decade 2020

Select Year 2024

Issue 12 July - Volume 3077, Issue 1

## PRELIMINARY

Preface: Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

*AIP Conf. Proc.* 3077, 010001 (2024) https://doi.org/10.1063/12.0024850

View article PDF

Committees: Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022

*AIP Conf. Proc.* 3077, 010002 (2024) https://doi.org/10.1063/12.0026137

View article PDF

## BIOLOGY

Postharvest technologies of celery (*Apium graveolens L.)* into powder: A comparison of conventional and modern methods

Faidliyah Nilna Minah; Dwi Ana Anggorowati; Cindy Mutiara Septani; Rini Kartika Dewi

*AIP Conf. Proc.* 3077, 020001 (2024) https://doi.org/10.1063/5.0201243

Abstract View article PDF

Effectiveness of areca *(Areca Catechu)* seed extract concentration as a green inhibitor and immersion time on steel corrosion control

Dewi Wahyuningtyas; Ayu Asmi Puspita; Eka Sulistyaningsih

*AIP Conf. Proc.* 3077, 020002 (2024) https://doi.org/10.1063/5.0203026

Abstract View article PDF

## CHEMISTRY

Synthesis and characterization of $SnO_2$ nanoparticles using electrolysis methods

Yanatra Budi Pramana; Ilham Jangkit Pamuncak; Rusdiyantoro Rusdiyantoro; M. Nushron Ali Mukhtar; Sotyohadi Sotyohadi

*AIP Conf. Proc.* 3077, 030001 (2024) https://doi.org/10.1063/5.0205531

Abstract View article PDF

In situ functionalization of ZnO nanoparticles for enhancing UV-light fastness and antibacterial activity of natural dye-colored batik fabric

Istihanah Nurul Eskani; Edia Rahayuningsih; Widi Astuti; Bidhari Pidhatika

*AIP Conf. Proc.* 3077, 030002 (2024) https://doi.org/10.1063/5.0203268

Abstract View article PDF

Preparation of nickel hydroxide nanoparticles with the electrolysis method

Yanatra Budi Pramana; M. Sochibul A'lal Ma'arif; Nabilla Nur Afifah; Akhmad Solikin; Krisyanti Budipramana

*AIP Conf. Proc.* 3077, 030003 (2024) https://doi.org/10.1063/5.0206172

Abstract View article PDF

Production of biodiesel from used cooking oil with zeolite supported cao catalyst: Effect of catalyst mass and transesterification reaction time

Elvianto Dwi Daryono; Jimmy Jimmy; Ferry Setiawan; Siti Sri Wahyuni

*AIP Conf. Proc.* 3077, 030004 (2024) https://doi.org/10.1063/5.0201746

Abstract View article PDF

Aerogel sensoric nanoparticles with controlled surface area and pore structure synthesized from bagasse ash

Nanik Astuti Rahman; Masrurotul Ajiza; Cindy Mutiara Septani

*AIP Conf. Proc.* 3077, 030005 (2024) https://doi.org/10.1063/5.0201232

Abstract View article PDF

## COMPUTER SCIENCE AND TECHNOLOGY

Literature review on brain computer interface (BCI) feature extraction using EEG signals

Ahsan Mumtaz; Iman Elawady; Ismail Rakip Karas

*AIP Conf. Proc.* 3077, 040001 (2024) https://doi.org/10.1063/5.0201283

Abstract View article PDF

Efficient content sharing using multi-cloud storage with selective RAID-like chunk retention control

Hyuga Nakazawa; Kengo Koyama; Shinji Sugaweara

*AIP Conf. Proc.* 3077, 040002 (2024) https://doi.org/10.1063/5.0202494

Abstract View article PDF

Comparison of Z-score, min-max, and no normalization methods using support vector machine algorithm to predict student's timely graduation

Muhammad Sholeh; Erna Kumalasari Nurnawati

*AIP Conf. Proc.* 3077, 040003 (2024) https://doi.org/10.1063/5.0202505

Abstract View article PDF

Measuring Islamic boarding school website effectiveness using usability analysis

Agung Teguh Wibowo Almais; A'la Syauqi; Roro Inda Melani; Ainatul Mardhiyah; Agus Maimun

*AIP Conf. Proc.* 3077, 040004 (2024) https://doi.org/10.1063/5.0205500

Abstract View article PDF

A typical lymphocyte cell counting system in blood smears of dengue fever patients based on digital image processing using improved counting morphology algorithm

Ahmad Fahrudi Setiawan; Yuyun Yueniwati Prabowowati Wajib; Kusworini; Setyawan P. Sakti

*AIP Conf. Proc.* 3077, 040005 (2024) https://doi.org/10.1063/5.0215602

Abstract View article PDF

---

Recognizing acne Vulgaris severity levels: An application of faster R-CNN and YOLO methods on medical images

Flasma Veronicha Hendryanna; Yan Watequlis Syaifudin; Muhammad Afif Hendrawan; Nobuo Funabiki; Indrazno Siradjuddin

*AIP Conf. Proc.* 3077, 040006 (2024) https://doi.org/10.1063/5.0201131

Abstract View article PDF

---

Low-cost system for identification of cataract maturity using LeNet CNN

Radimas Putra Muhammad Davi Labib; Dwangga Rizqia Meidyan Syahputra; Ririn Katherina Maturbongs; Amandarika Widyatamara; Mochamad Bayu Aditama; Elvan Dwi Nur Asyifa

*AIP Conf. Proc.* 3077, 040007 (2024) https://doi.org/10.1063/5.0201807

Abstract View article PDF

---

Opinion mining on Indonesian tourism TikTok video content using fasttext and multilayer long short-term memory

Dony Ariyus; Danny Manongga; Irwan Sembiring

*AIP Conf. Proc.* 3077, 040008 (2024) https://doi.org/10.1063/5.0202656

Abstract View article PDF

---

Mapping technology of cultural heritage for sustainable urban area management at Indonesia

Lea Kristi Agustina; Agung Budi Harto; Deni Suwardhi; Ketut Wikantika

*AIP Conf. Proc.* 3077, 040009 (2024) https://doi.org/10.1063/5.0212752

Abstract View article PDF

---

Web-based GIS spatial decision support system for infrastructural maintenance of roads and irrigation facilities in Central and East Sumba

Togi Nainggolan; Silvester Sari Sai; Abraham Lomi; Adkha Yulianandha Mabrur; Ratri Andinisari

*AIP Conf. Proc.* 3077, 040010 (2024) https://doi.org/10.1063/5.0202467

Abstract View article PDF

---

Digital signage: Digital transforming content as an information service in society 5.0

Dimas Indra Laksmana; Sri Indriani; Kiswandono; Aria Dian Tri Wahyuni

*AIP Conf. Proc.* 3077, 040011 (2024) https://doi.org/10.1063/5.0202144

Abstract View article PDF

---

Technology and characteristics of intelligent tutoring system for air traffic controller surveillance training: A systematic review

Dian Anggraini Purwaningtyas

*AIP Conf. Proc.* 3077, 040012 (2024) https://doi.org/10.1063/5.0201749

Abstract View article PDF

Enterprise architecture design for startup companies using the application of the open group architecture framework architecture development method

Nyoman Ayu Nila Dewi; Riza Wulandari; I. Ketut Widhi Adnyana

*AIP Conf. Proc.* 3077, 040013 (2024) https://doi.org/10.1063/5.0201792

Abstract View article PDF

Effective machine learning techniques for brain pathology classification on mr images

Ruaa M. Mahmood; Nehad T. A. Ramaha; Ismail R. Karas

*AIP Conf. Proc.* 3077, 040014 (2024) https://doi.org/10.1063/5.0212771

Abstract View article PDF

Ve.Rubric: A rapid application development (RAD) for vocational education rubric assessment tool

Neni Rohaeni; Nenden Rani Renikasari; Yoyoh Jubaedah; Shofa Fithriturrohmi Yusuf

*AIP Conf. Proc.* 3077, 040015 (2024) https://doi.org/10.1063/5.0203219

Abstract View article PDF

Convolutional neural networks for text classification: A study on public activity restriction

H. Anggit Taba; Hari Suparwito

*AIP Conf. Proc.* 3077, 040016 (2024) https://doi.org/10.1063/5.0201145

Abstract View article PDF

Improving of anticancer compound identification model for medicinal plant's LCMS data

Iwan Binanto

*AIP Conf. Proc.* 3077, 040017 (2024) https://doi.org/10.1063/5.0201202

Abstract View article PDF

Preliminary research for provision of Javanese script image dataset from Javanese script printed book

Anastasia Rita Widiarti; Gabriel Ryan Prima; Ciprianus Kuntoro Adi

*AIP Conf. Proc.* 3077, 040018 (2024) https://doi.org/10.1063/5.0201159

Abstract View article PDF

Online course administration system with QR code

Boy Yuliadi; Magito Magito; Margono Sugeng; Herlinda Herlinda

*AIP Conf. Proc.* 3077, 040019 (2024) https://doi.org/10.1063/5.0202053

Abstract View article PDF

The last-ten years of big data in vocational education: A systematic review

Sherly Rahmawati; Theodore Oduro-Okyireh; Emmanuel Obbobi Tettehfio; Ade Gafar Abdullah; Budi Mulyanti; Ona Pebriani; Roni Arya Gunawan

*AIP Conf. Proc.* 3077, 040020 (2024) https://doi.org/10.1063/5.0202080

Abstract View article PDF

Triple filter test a simple technique preventing the spread of HOAX

Henri Septanto; Ari Hidayatullah; Ryani Dhyan Parashakti

*AIP Conf. Proc.* 3077, 040021 (2024) https://doi.org/10.1063/5.0203284

Abstract View article PDF

## ENGINEERING

A modified iterative method for solving the Hamilton-Jacobi-Bellman equation

Hartono Hartono

*AIP Conf. Proc.* 3077, 050001 (2024) https://doi.org/10.1063/5.0201848

Abstract View article PDF

Alternating current electric generator design simulation using PhET simulator

Djoko Untoro Suwarno

*AIP Conf. Proc.* 3077, 050002 (2024) https://doi.org/10.1063/5.0201215

Abstract View article PDF

Analysis of electric protection system with arrester on catenary network for electric train power supply

Erfiana Wahyuningsih; Rizal Wahyu Fatoni; Dessy Kristyawati; Ganjar Febriyani Pratiwi

*AIP Conf. Proc.* 3077, 050003 (2024) https://doi.org/10.1063/5.0201163

Abstract View article PDF

Analysis of public transit system fare policy in Indonesia using big data on post Covid-19 pandemic: A case study of MRT Jakarta Indonesia

Mira Lestira Hariani; Fariz Ramadhan

*AIP Conf. Proc.* 3077, 050004 (2024) https://doi.org/10.1063/5.0201147

Abstract View article PDF

Analysis of the increasing runway's PCN value on the growth of aircraft movement (case study: I Gusti Ngurah Rai International Airport)

I. Putu Dika Irvayana; Yackob Astor; Atmy Verani Rouly Sihombing; Asep Sundara

*AIP Conf. Proc.* 3077, 050005 (2024) https://doi.org/10.1063/5.0201122

Abstract View article PDF

Analytical and dynamic loading test evaluation of fly over "X" foundations, Bandung city, Indonesia

Aditia Febriansya; Iskandar Iskandar; Mulyadi Yuswandono; Andri Krisnandi Somantri; Nadya Amelia; Rubinaufal Arfariq Yahya

*AIP Conf. Proc.* 3077, 050006 (2024) https://doi.org/10.1063/5.0203207

Abstract View article PDF

ASP.NET MVC web API as powerful IoT controller from cloud

Randy Rahmanto; Sulistyo Widodo; Belinda Ayuningtyas

*AIP Conf. Proc.* 3077, 050007 (2024) https://doi.org/10.1063/5.0202062

Abstract View article PDF

Compliance of standards for pedestrian facilities in Cimahi city Indonesia based on pedestrian technical guidelines

Agah Muhammad Mulyadi; Fitri Yulia Rahmawati; Sidik Baitul Rochmat; Casare Adi Nugraha; Lulu Qonita Lutfiya; Ferry Rusgiyarto

*AIP Conf. Proc.* 3077, 050008 (2024) https://doi.org/10.1063/5.0204809

Abstract View article PDF

Compressive strength of bacterial-based concrete materials using Bacillus megaterium bacteria

Mutia Gina Savira; Ujang Ruslan; Keryanti Keryanti; Luthfi Muhammad Mauludin

*AIP Conf. Proc.* 3077, 050009 (2024) https://doi.org/10.1063/5.0201794

Abstract View article PDF

Constructal heat release of radial permanent magnet generator

A. Prasetyadi; Ronny Dwi Agusulistyo

*AIP Conf. Proc.* 3077, 050010 (2024) https://doi.org/10.1063/5.0201388

Abstract View article PDF

Air circulation types on Albizia Chinensis refrigerated drying

Petrus Kanisius Purwadi; A. Prasetyadi

*AIP Conf. Proc.* 3077, 050011 (2024) https://doi.org/10.1063/5.0201391

Abstract View article PDF

Data transmission performance analysis of virtual reality system supported with IoT technology

Nuske Lisa Marlissa; Damar Widjaja

*AIP Conf. Proc.* 3077, 050012 (2024) https://doi.org/10.1063/5.0201262

Abstract View article PDF

Design of air conditioning system in the archive depot building of the department of archives and library of Depok

Madarif Prawibowo; Komarudin Komarudin; Wahyu Fajar Nuri

*AIP Conf. Proc.* 3077, 050013 (2024) https://doi.org/10.1063/5.0202162

Abstract View article PDF

Development of control system and monitoring via the internet (IoT) based on Arduino UNO on the use of condensate water in the refrigerator

Eddy Erham; Markus Markus; Ary Surjanto; Rafa Naufal Zafran

*AIP Conf. Proc.* 3077, 050014 (2024) https://doi.org/10.1063/5.0202458

Abstract View article PDF

Evaluation of heat loss in distribution pipeline cold water in chiller fan coil unit

Ade Suryatman Margana; Sugiyarto Sugiyarto; Luga Martin Simbolon; Bowo Yuli Prasetyo; Susilawati Susilawati; Syifa Azzahra Hayat

*AIP Conf. Proc.* 3077, 050015 (2024) https://doi.org/10.1063/5.0203251

Abstract | View article | PDF

---

Experimental study on the performance of centralized air conditioning system due to different outdoor air conditions

K. Sumeru; T. P. Pramudantoro; V. M. A. Zulfikar; M. F. Sukri

*AIP Conf. Proc.* 3077, 050016 (2024) https://doi.org/10.1063/5.0202243

Abstract | View article | PDF

---

Flood area mapping and flood hazard assessment in Utama Urban village, South Cimahi

Iin Karnisah; Enung Enung; Moch. Yusup; Beny Mulyana Sukandar; Yackob Astor; Idmoneia Bianca Nugraha; Tety Tamariska Oktiara Bangun; Frenki Tres Widyantoro

*AIP Conf. Proc.* 3077, 050017 (2024) https://doi.org/10.1063/5.0201089

Abstract | View article | PDF

---

Flood vulnerability mapping in Cimahi city, Indonesia

Iin Karnisah; Enung Enung; M. Yusup; Beny Mulyana Sukandar; Yackob Astor; Ainnaya Sajida; Hana Fitri Khairani

*AIP Conf. Proc.* 3077, 050018 (2024) https://doi.org/10.1063/5.0201091

Abstract | View article | PDF

---

Guitar chord recognition using MFCC based feature extraction with Kaiser windowing

Linggo Sumarno

*AIP Conf. Proc.* 3077, 050019 (2024) https://doi.org/10.1063/5.0201877

Abstract | View article | PDF

---

The fit and predict COVID-19 using an extended compartmental model in the context of Indonesia

Indrazno Siradjuddin; Bella Cahya Ningrum; Inta Nurkhaliza Agiska; Arwin Datumaya Wahyudi Sumari; Yan Watequlis Syaifudin; Rosa Andrie Asmara; Nobuo Funabiki

*AIP Conf. Proc.* 3077, 050020 (2024) https://doi.org/10.1063/5.0201201

Abstract | View article | PDF

---

Optimizing the implementation of the XXX mall project with the integration of the earned value and time cost trade off methods

Rifaldi Adi Saputra; Era Agita Kabdiyono

*AIP Conf. Proc.* 3077, 050021 (2024) https://doi.org/10.1063/5.0201137

Abstract | View article | PDF

---

Pavement conditions evaluation based on guidelines for pavement condition index PCI) with the assistance of unmanned aerial vehicle (UAV)

Retno Utami; Iman Ruchiat; Yackob Astor; Atmy Verani Rouly Sihombing; R. Desutama Rachmat Bugi Prayogo; Dewi Amalia Pertiwi; Reghina Mulya Sari

*AIP Conf. Proc.* 3077, 050022 (2024) https://doi.org/10.1063/5.0201093

Abstract | View article | PDF

Road performance assessment after the existence fly over on roads in Indonesia

Alman Rahadiansyah Willianto; Muhammad Raihan Nugraha; Yackob Astor; Asep Sundara

*AIP Conf. Proc.* 3077, 050023 (2024) https://doi.org/10.1063/5.0201095

Abstract | View article | PDF

Planning of bicycle lane as sustainable transportation to support post pandemic adaptation in Cimahi city, Indonesia

Agah Muhammad Mulyadi; Anisa Mardiyanti Putri; Sally Nuraeni; Fairuz Albi Asyhari; Aldo Organami; Hanafi Hanafi

*AIP Conf. Proc.* 3077, 050024 (2024) https://doi.org/10.1063/5.0204807

Abstract | View article | PDF

Reverse engineering of steam turbines for national manufacturing industry independence

D. Febriansyah; R. Harmadi; K. Herbandono; Faisal Faisal; C. S. A. Nandar

*AIP Conf. Proc.* 3077, 050025 (2024) https://doi.org/10.1063/5.0201820

Abstract | View article | PDF

SCADA application for popcorn cooking and packaging system using PLC and internet

Theresia Prima Ari Setiyani; Geraldine Valda Prakusya Putri Ayu; Ignatia Diva Saniscara

*AIP Conf. Proc.* 3077, 050026 (2024) https://doi.org/10.1063/5.0201806

Abstract | View article | PDF

Analysis bending capacity of camphor wood-concrete composite beams with carbon fiber reinforced polymer

Pamella Meidina Sri Rezeki; Mujiman Mujiman

*AIP Conf. Proc.* 3077, 050027 (2024) https://doi.org/10.1063/5.0203212

Abstract | View article | PDF

The effect of adding marble dust on compressive strength and bearing capacity value for soft clay soil

Syahril Syahril; Agus Suyono; Hendry Hendry; Muchtar Muchtar; Muhammad Raihan Riandi

*AIP Conf. Proc.* 3077, 050028 (2024) https://doi.org/10.1063/5.0201795

Abstract | View article | PDF

The effect of atmospheric temperature on brine cooling performance using nylon tube on liquid line and suction line

Arda Rahardja Lukitobudi; Sugiyarto; A. P. Edi Sukamto; Triaji Pangripto Pramudantoro; Cindy Gamas; Verino Apriliano Prio Utomo

*AIP Conf. Proc.* 3077, 050029 (2024) https://doi.org/10.1063/5.0207227

Abstract | View article | PDF

The effect of austenization temperature variations on the mechanical properties of stainless steel

Janatika Putra Perdana; Margono Sugeng

*AIP Conf. Proc.* 3077, 050030 (2024) https://doi.org/10.1063/5.0203194

Abstract View article PDF

### The effect of rice husk ash and phosphoric acid as soft soil stabilizing agent for plasticity index value

Muhammad Raihan Riandi; S. Syahril

*AIP Conf. Proc.* 3077, 050031 (2024) https://doi.org/10.1063/5.0201119

Abstract View article PDF

### The effect of squeezing force to the shear strength of sengon wood and coconut wood using Poly Vinyl Acetate adhesive

Muhammad Taufan; Mujiman Mujiman; Yulianto Petrus Krisologus

*AIP Conf. Proc.* 3077, 050032 (2024) https://doi.org/10.1063/5.0214732

Abstract View article PDF

### The implementation of MPPT incremental conductance method with boost converter on PV system

Dorothy Patricia Monique; Yehezkiel Krisma; Petrus Setyo Prabowo; Bernadeta Wuri Harini

*AIP Conf. Proc.* 3077, 050033 (2024) https://doi.org/10.1063/5.0201808

Abstract View article PDF

### The implementation of MPPT Perturb and observe method with boost converter on PV system

Agnesia Felita; Yehezkiel Krisma; Petrus Setyo Prabowo; Bernadeta Wuri Harini

*AIP Conf. Proc.* 3077, 050034 (2024) https://doi.org/10.1063/5.0201805

Abstract View article PDF

### Utilization of unmanned aerial vehicle for pavement condition evaluation with surface distress index method on the Bandung-Subang road, Indonesia

Yackob Astor; Retno Utami; Atmy Verani Rouly Sihombing; Rd. Bugi Prayogo Desutama; Saldila Pramestu; Syahreza Apriansyah

*AIP Conf. Proc.* 3077, 050035 (2024) https://doi.org/10.1063/5.0201319

Abstract View article PDF

### Integrated tourism village system (IToViS) development for tourism village

Ni Luh Ayu Kartika Yuniastari Sarja; Made Riyan Adi Nugroho; I. Gde Agus Jaya Sadguna; I. Nyoman Meirejeki; Kadek Nita Sumiari; Ni Ketut Pradani Gayatri Sarja

*AIP Conf. Proc.* 3077, 050036 (2024) https://doi.org/10.1063/5.0201227

Abstract View article PDF

### Quality improvement of fungicide products packaging using FMEA and continuous improvement

Alan Maulidan Firdaus; Ellysa Nursanti; Fuad Achmadi

*AIP Conf. Proc.* 3077, 050037 (2024) https://doi.org/10.1063/5.0203229

Abstract View article PDF

### Determining preventive maintenance interval to increase the reliability of air turbine engine starter

Ellysa Nursanti; Sibut Sibut; Sunarjono Prijohutomo

*AIP Conf. Proc.* 3077, 050038 (2024) https://doi.org/10.1063/5.0203228

Abstract View article PDF

Land management in fisherman's settlement as slum control, in Tanah Laut Regency, South Kalimantan

Ghestiar Kharisma Kusumo; Agung Witjaksono; Maria C. Endarwarti

*AIP Conf. Proc.* 3077, 050039 (2024) https://doi.org/10.1063/5.0209768

Abstract View article PDF

Optimal integration of wind turbine into the grid with artificial intelligence-based microgrid controller

Ni Putu Agustini; I. Made Wartana

*AIP Conf. Proc.* 3077, 050040 (2024) https://doi.org/10.1063/5.0201349

Abstract View article PDF

Energy absorption and deformation pattern of honeycomb hybrid crash box under frontal load

Fina Andika Frida Astuti; Moch. Agus Choiron; Anindito Purnowidodo; Yudy Surya Irawan

*AIP Conf. Proc.* 3077, 050041 (2024) https://doi.org/10.1063/5.0201851

Abstract View article PDF

Landslide mitigation through NDSI-based soil erodibility value prediction on coffee land in Wajak subdistrict, Malang Regency, East Java

Dinna Hadi Sholikah; Kurniawan Sigit Wicaksono; Soemarno Soemarno; Istika Nita; Uci Riandayani Damanik; Muhammad Rifqi Al Jauhary; Raihan Naufal; Aldo Jetco Husada; Syifa Salsabilla Bratawijaya; Destantri Kridiati

*AIP Conf. Proc.* 3077, 050042 (2024) https://doi.org/10.1063/5.0209394

Abstract View article PDF

A medicine and food delivery robot for Covid-19 hospital using Labview MyRIO FPGA

Irmalia Suryani Faradisa; Agung Darmawan; Yudi Limpraptono; Abraham Lomi

*AIP Conf. Proc.* 3077, 050043 (2024) https://doi.org/10.1063/5.0201841

Abstract View article PDF

Design of solar panel for electric car power supply with four selenoid in-line engine

Aji Pranoto; Syafriyudin; Prastyono E. Pambudi; Venditias Yudha; Ellyawan S. Arbintasrso

*AIP Conf. Proc.* 3077, 050044 (2024) https://doi.org/10.1063/5.0202303

Abstract View article PDF

Spare parts inventory control to minimize total inventory cost using continuous review system and periodic review system approaches

Rahayu Khasanah; Masih Ingdana Fadillah; Imam Sodikin; Joko Susetyo

*AIP Conf. Proc.* 3077, 050045 (2024) https://doi.org/10.1063/5.0202654

Abstract View article PDF

Real-time structural health monitoring (SHM) using strain gauge Arduino sensor at reinfocement concrete under static and impact loading

Vega Aditama; Sri Murni Dewi; Ari Wibowo; Ming Narto Wijaya

*AIP Conf. Proc.* 3077, 050046 (2024) https://doi.org/10.1063/5.0202079

Abstract View article PDF

Treatment performance of Tlogomas communal wastewater treatment plant

Evy Hendriarianti; Candra Dwiratna Wulandari; Andika Yoga Pradana; Suhaena Wisma Ernia Sindy

*AIP Conf. Proc.* 3077, 050047 (2024) https://doi.org/10.1063/5.0202471

Abstract View article PDF

Crack pattern in concrete beam continuous shear reinforcement with numerical method

Mohammad Erfan; Yosimson P. Manaha; W. S. Hadi Surya; Vega Aditama

*AIP Conf. Proc.* 3077, 050048 (2024) https://doi.org/10.1063/5.0205765

Abstract View article PDF

Evaluating energy efficiency and conservation, water conservation, indoor health and comfort on conservation building

Aurelius Andri Wibowo; Maranatha Wijayaningtyas; Lalu Mulyadi

*AIP Conf. Proc.* 3077, 050049 (2024) https://doi.org/10.1063/5.0202247

Abstract View article PDF

Analysis of appropriate site development on public building with greenship criteria green building

Lea Mahdarina; Maranatha Wijayaningtyas; Lila Ayu Ratna Winanda; Deviany Kartika

*AIP Conf. Proc.* 3077, 050050 (2024) https://doi.org/10.1063/5.0202248

Abstract View article PDF

Low-cost high-performance MEMS inertia measurement unit (IMU) for seismic activity monitoring

Bima R. P. D. Palevi; Djoko H. Praswanto; Ratri Andinisari; Citra D. Megawati; Rachmadi Setiawan

*AIP Conf. Proc.* 3077, 050051 (2024) https://doi.org/10.1063/5.0203244

Abstract View article PDF

Participatory ergonomics-based work productivity strategy for Wijaya Kusuma bakery’s home industry

P. Vitasari; Julian Candra Purnama; Sony Harianto; Fuad Achmadi; Suriya Kumar Sinnadurai

*AIP Conf. Proc.* 3077, 050052 (2024) https://doi.org/10.1063/5.0202517

Abstract View article PDF

The use of smart contracts for third-party comparison web logistics

Nataniel Albert Angstein; Joniarto Parung

*AIP Conf. Proc.* 3077, 050053 (2024) https://doi.org/10.1063/5.0202066

Abstract View article PDF

Implementation of a low-cost embedded multi-camera system for leaf plant monitoring in the greenhouse

Aryuanto Soetedjo; Evy Hendriarianti; Muhammad Suriansyah; M. Rifki Abdilah; M. Syahriel; H. M. Mohamad Khafil

*AIP Conf. Proc.* 3077, 050054 (2024) https://doi.org/10.1063/5.0202538

Abstract View article PDF

Voltage stability analysis using probability density function with real load on Karangploso's Feeder Singosari distribution system

Irrine Budi Sulistiawati; Ahmad Iqbal Zajuli; Sugeng Priyanto; Awan Uji Krismanto; Adlan Bagus Pradana; Aji Akbar Firdaus

*AIP Conf. Proc.* 3077, 050055 (2024) https://doi.org/10.1063/5.0202466

Abstract View article PDF

Rural thematic map based on a strategical issue approach

Muhammad Nelza Mulki Iqbal; Antonio Heltra Pradana; Debby Budi Susanti

*AIP Conf. Proc.* 3077, 050056 (2024) https://doi.org/10.1063/5.0201612

Abstract View article PDF

The first order Fischer-Tropsch reaction rate constant calculation from carbon monoxide based conversion data

Jimmy Jimmy; Elvianto Dwi Daryono; Harimbi Setyawati

*AIP Conf. Proc.* 3077, 050057 (2024) https://doi.org/10.1063/5.0203052

Abstract View article PDF

Blockchain technology in wood raw material supply chain management – A bibliometric analysis and review

Velicia Oktaviani Susanto; Joniarto Parung

*AIP Conf. Proc.* 3077, 050058 (2024) https://doi.org/10.1063/5.0202067

Abstract View article PDF

Absolute locations of earthquakes in eastern java determined by using a minimum 1D P-wave velocity model

Ratri Andinisari; Andrean V. H. Simanjuntak; Rahadatul A. N. Dhanarsari

*AIP Conf. Proc.* 3077, 050059 (2024) https://doi.org/10.1063/5.0201144

Abstract View article PDF

Utilization of automatic test case generation methods for various system specifications

Yuto Fujita; Kiyoshi Ueda

*AIP Conf. Proc.* 3077, 050060 (2024) https://doi.org/10.1063/5.0206062

Abstract View article PDF

Transforming blackwater into clean water – Is it possible?

Lies Kurniawati Wulandari

*AIP Conf. Proc.* 3077, 050061 (2024) https://doi.org/10.1063/5.0205542

Abstract View article PDF

Geometric quality of orthophoto from aerial images obtained by UAV's consumer grade camera: Lesson learnt

Silvester Sari Sai; Martinus Edwin Tjahjadi; Masrurotul Ajiza; Hery Purwanto

*AIP Conf. Proc.* 3077, 050062 (2024) https://doi.org/10.1063/5.0202468

Abstract View article PDF

Geometric quality of UAV's consumer grade camera: Lessons learnt

Silvester Sari Sai; Martinus Edwin Tjahjadi; Alifah Norani; Ketut Tomy Suhari

*AIP Conf. Proc.* 3077, 050063 (2024) https://doi.org/10.1063/5.0202469

Abstract View article PDF

Effect of the variation of composted solid waste treatment on the addition of bioactivators at Loka Bhakti 3R solid waste tratment facility, Pakisaji Malang, Indonesia

Ni Wayan Diana Apriani; Hardianto Hardianto; Anis Artiyani; Agung Witjaksono

*AIP Conf. Proc.* 3077, 050064 (2024) https://doi.org/10.1063/5.0201200

Abstract View article PDF

Potential of cheese waste (whey) as liquid organic fertilizer

Mohammad Istnaeny Hudha; Nanik Astuti Rahman; Anitarakhmi Handaratri; Feisal Adam Zulkarnaen; Bagas Swandana

*AIP Conf. Proc.* 3077, 050065 (2024) https://doi.org/10.1063/5.0203182

Abstract View article PDF

The effects of rail transport development to the residents

Nur Hafizah Juhari; Alain Tiew Kai Lun; Puteri Ameera Mentaza Khan; Nurhayati Khair; Amalina Azmi

*AIP Conf. Proc.* 3077, 050066 (2024) https://doi.org/10.1063/5.0203225

Abstract View article PDF

Preliminary assessment on the performance of long distance wireless data transmission for disaster early warning system

Michael Ardita; Alfarid Hendro Yuwono; Gatot Kusrahardjo; Radimas P. M. D. Labib; Kartiko Ardi Widodo

*AIP Conf. Proc.* 3077, 050067 (2024) https://doi.org/10.1063/5.0216537

Abstract View article PDF

Experimental study a low speed-one phase generator with permanent magnetic radial flux

Syafriyudin Syafriyudin; Muhammad Suyanto; Aji Pranoto

*AIP Conf. Proc.* 3077, 050068 (2024) https://doi.org/10.1063/5.0202470

Abstract View article PDF

Design and analysis of cabin carbon monoxide warning system

Erfan Rohadi; Rudy Ariyanto; Indrazno Siradjuddin; Kristinanti Charisma

*AIP Conf. Proc.* 3077, 050069 (2024) https://doi.org/10.1063/5.0203224

Abstract View article PDF

RESEARCH ARTICLE | JULY 12 2024

# Guitar chord recognition using MFCC based feature extraction with Kaiser windowing

Linggo Sumarno

*AIP Conf. Proc.* 3077, 050019 (2024)
https://doi.org/10.1063/5.0201877

# Guitar Chord Recognition using MFCC Based Feature Extraction with Kaiser Windowing

Linggo Sumarno[1, a)]

[1]Sanata Dharma University, Kampus III, Paingan Maguwoharjo, Depok, Sleman, Yogyakarta 55282, Indonesia

[a)] Corresponding author: lingsum@usd.ac.id

**Abstract.** Based on the previous studies of the guitar chord recognition systems, there is an indication that a study can still be carried out. In this case, an indication to study a lower number of coefficients of feature extraction in a guitar chord recognition system. The purpose of this study is to obtain a lower number of coefficients of feature extraction in a guitar chord recognition system than the previous studies. In this study, the guitar chord recognition system uses MFCC (Mel Frequency Cepstral Coefficients) based feature extraction with Kaiser windowing. This study evaluated three parameters from the system, namely the lowest mel filter frequency and the number of mel filters in the mel filter bank, and also the shape factor of the Kaiser window. The results showed that by using only four coefficients of feature extraction, it could achieve an accuracy of up to 92.14%. As a note this accuracy was carried out by using 140 test chords.



## INTRODUCTION

In a recognition system, usually there is a sub-system called feature extraction. The purpose of this sub-system is to determine the significant information from a huge quantity of data. By using this significant information, the system will use less data for data processing. In a chord recognition system, there are two approaches that can be used for feature extraction. The first one is chroma-based feature extraction, and the second one is non-chroma-based feature extraction. For chroma-based feature extraction, the coefficients of feature extraction are associated with the power of the fundamental frequencies of the chord. In contrast, for non-chroma-based feature extraction, the coefficients of feature extraction are not associated with the power of the fundamental frequencies of the chord.

PCP (Pitch Class Profile) [1] is a feature extraction method that uses a chroma-based approach. This PCP method uses 12 coefficients of feature extraction. This is the original PCP method. After that, there are several derivatives of the original PCP method. Some of these derivatives include CRP (Chroma DCT-Reduced log Pitch) Enhanced PCP [2], Improved PCP [3], and Harmonic PCP [4]. These derivatives also use 12 coefficients of feature extraction.

MFCC (Mel Frequency Cepstral Coefficients) [5,6] and segment averaging [7,8] are two non-chroma-based feature extraction methods. The conventional MFCC feature extraction method only uses a number of 8–13 coefficients of feature extraction [5]. Recent studies of the MFCC feature extraction methods for chord recognition continue to use a number of 13 coefficients of feature extraction [9,10]. In the meantime, recent studies of segment averaging feature extraction for chord recognition use the lower number of coefficients of feature extraction down to eight [7] and six [8] respectively. In this case, by using the lower numbers of these coefficients, the chord recognition system was able to achieve an accuracy of more than 90%.

From the standpoint of the lower numbers of coefficients of feature extraction [7,8], a study for lowering the number of these coefficients still can be carried out. The reduced number of these coefficients will benefit a smaller quantity of data in data processing. The use of this reduced number of these coefficients will help chord recognition implementations employing FPGA (Field Programmable Gate Array) [11,12]. We can use this FPGA to build a

*Proceedings of the Transdisciplinary Symposium on Engineering and Technology (TSET) 2022*
AIP Conf. Proc. 3077, 050019-1–050019-7; https://doi.org/10.1063/5.0201877
Published under an exclusive license by AIP Publishing. 978-0-7354-4964-0/$30.00

system-on-chip. This system can be taped out as an ASIC (Application Specific Integrated Circuit) for electronic devices.

This study proposes evaluating three parameters to obtain less than eight coefficients of feature extraction for a chord recognition system using MFCC with Kaiser windowing. The three parameters are the lowest mel filter frequency and the number of mel filters in the mel filter bank, and also the shape factor of the Kaiser window. As a first note, by using less than eight coefficients of feature extraction, the chord recognition could achieve an accuracy of above 90%. As a second note, the limit value of 90% is the limit where we can see that by evaluating these three parameters, this study is better than the previous ones.

# RESEARCH METHODOLOGY

## The Chord Recognition System

A block diagram of the chord recognition system that was developed in this study is shown in Fig. 1. As a note, it was implemented using Octave software. In more detail, the chord recognition system that is in Fig. 1 is described as below.

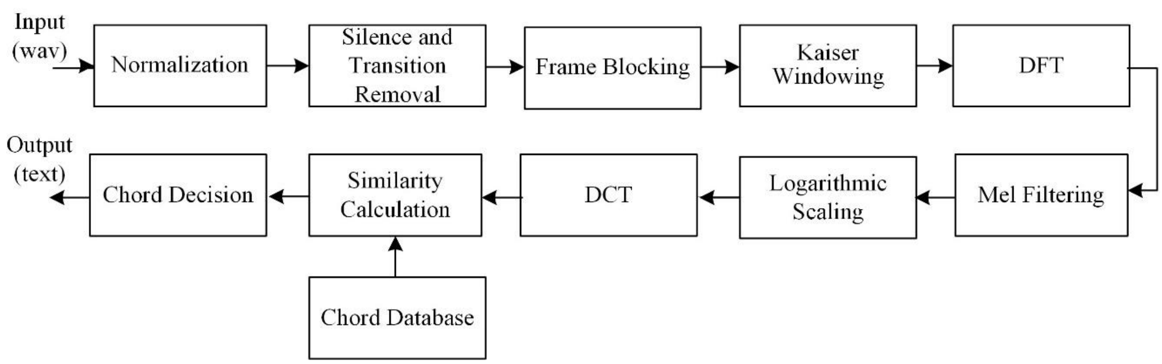


**FIGURE 1.** The chord recognition system

### *Input*

The chord recognition system uses a chord signal in WAV format as input. This signal is a type of isolated signal. It was recorded from a Yamaha CPX 500-II guitar. This guitar is shown in Fig. 2. This study used seven major chords, namely C, D, E, F, G, A, and B [7,8]. These chords were obtained by recording them at a 5 kHz sampling frequency. This frequency has satisfied the sampling theorem of Shannon [13] as follows.

$$f_s \geq 2f_{max} \tag{1}$$

where $f_{max}$ is the maximum frequency component of the signal, and $f_s$ is the sampling frequency of the signal. Since the maximum frequency component of the above-mentioned chords is 392 Hz, the above-mentioned sampling frequency of the signal has satisfied the sampling theorem of Shannon. This maximum frequency originates from the tone G4 found in the chord G. In this study, a sample time of 2 seconds was used since, by using eye inspection, it was adequate to get the steady state part of the recorded chord signal.

**FIGURE 2.** Yamaha CPX 500-II guitar

*Normalization, Silence and Transition Removal*

Normalization is used to adjust the maximum value in the array of signal data to 1 or -1. This normalization is performed in order to resolve the problem of signal level during recording.

Silence and transition removal is used to remove regions of silence and transition that appear in the signal data array. As a note, These regions are removed since there is no signal information in these regions. First, using eye inspection, the silence region on the left-side part of the signal data array could be removed using a |0.5| threshold value. If the data was less than |0.5| when scanned from left to right, it was removed. Second, using eye inspection, the transition region on the leftmost-side part can be removed with a duration time of 200ms.

*Frame Blocking*

Frame blocking is used to split lengthy signal data into shorter signal frames [14]. Previous MFCC study used signal frames that had a length of 15–25ms [15]. This signal frame has a 50% overlap between the adjacent frames. In this case, frame overlap is needed in order to keep the continuity of signal within frames. Based on the evaluation, this study used a signal frame that had a length of 32ms. This signal frame also had a 50% overlap between the adjacent frames. This evaluation was performed by evaluating the optimal length of the signal frame and also the overlap between the adjacent frames, which gives the highest chord accuracy.

*Kaiser Windowing*

Windowing is used to reduce the level of discontinuities at the portion of the signal frame's edges. These discontinuities will cause extra signals in the magnitude spectrum. These signals are known as harmonic signals. Therefore, if these discontinuities are reduced, harmonic signals will be diminished. The Kaiser window was used in this study. This window is commonly used in signal processing [16]. It is expressed as the following.

$$w_K(m) \triangleq \begin{cases} \dfrac{I_0\left(\beta\sqrt{1-\left(\dfrac{m}{M/2}\right)^2}\right)}{I_0(\beta)}, & -\dfrac{M-1}{2} \le m \le \dfrac{M-1}{2} \\ 0, & \text{elsewhere} \end{cases} \tag{2}$$

where $I_0$ is the zero-order modified Bessel function of the first kind, $\beta$ is the shape factor, and $M$ is the length of window. The expression of $I_0$ is shown below.

$$I_0(x) \triangleq \sum_{k=0}^{\infty}\left[\frac{\left(\frac{x}{2}\right)^k}{k!}\right]^2 \tag{3}$$

*DFT (Discrete Fourier Transform)*

DFT is used to generate a magnitude spectrum frame from a windowed frame. Because the magnitude spectrum is symmetric, this study only use half of the left side. As a note, that magnitude spectrum frame is needed since the next process, mel filtering, will perform filtering in the frequency domain.

*Mel Filtering*

A mel is defined as a unit of measurement that is based on the perceived (felt) frequency of the human ear. This perceived frequency does not have a linear relation with the actual frequency of the tone. The equation for mel's approximation to physical frequency is given below.

$$f_{mel} = 1127\ ln\left(1 + \frac{f_{phy}}{700}\right) \tag{4}$$

where $f_{phy}$ is physical frequency, and $f_{mel}$ is perceived frequency. A mel filtering is shown in Fig. 3. This mel filtering is used in this study. The input is a magnitude spectrum frame and the output is a 1D array of mel frequency coefficients. A number of *N* mel filters exist in the mel filter bank.

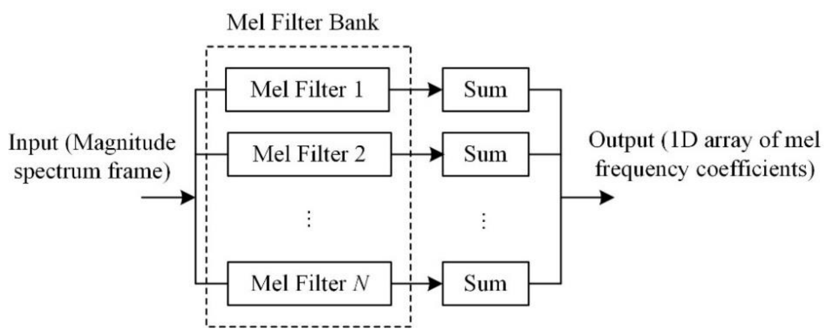


**FIGURE 3**. Mel filtering

The type of the above-mentioned mel filters is a bandpass filter. The center frequencies of these bandpass filters on the frequency axis are not uniformly spaced. In more detail, these center frequencies are spaced not uniformly using a nonlinear function as shown in equation (4). The triangular shape is the most commonly used shape for mel filters [5]. This type of shape was used in this study.

In this study, in this mel filtering process, all magnitude spectrum frames are processed simultaneously. As seen in Fig. 3, each magnitude spectrum frame will result in a 1D array of mel frequency coefficients. Then, a number of magnitude spectrum frames will result in a number of 1D arrays of mel frequency coefficients. Finally, all of these 1D arrays are organized into a 2D array of mel frequency coefficients.

*Logarithmic Scaling and DCT*

Logarithmic scaling is used to calculate the logarithm of every element in the above-mentioned 2D array of mel frequency coefficients. In this case, this logarithmic scaling is needed for the calculation of the cepstral coefficients.

DCT is used to calculate a 2D array of cepstral coefficients from a 2D array of mel frequency coefficients. This calculation is carried out by using 2D DCT. The upper left portion of the 2D array of cepstral coefficients contains a large amount of information about the input signal. In this study, this information was acquired via zigzag scanning. The zigzag scanning yielded a 1D array of cepstral coefficients. Several of that array's first numbers are referred to as the coefficients of feature extraction of the input signal. The zeroth coefficient from that array was not used in this study since it contains only a small amount of particular information [5].

*Similarity calculation, chord decision, and output*

A number of values of similarity are calculated between an array of a chord coefficients that extracted from the input signal and a number arrays of chord reference coefficients stored in a chord database. In this study, there are seven similarity values since there are seven arrays of chord reference coefficients stored in a chord database. In this case, each chord reference coefficient corresponds with a chord of C, D, E, F, G, A, or B. The values of similarity were calculated using cosine similarity. The consideration of using this similarity is that it is used widely to calculate the similarity value [17,18].

The chord decision determines an output text, which is associated with the chord information in the input signal. That output text, namely C, D, E, F, G, A, or B. The following describes the approach for determining the output text.

1. Search the biggest similarity value among the above-mentioned seven similarity values.
2. Search a chord text that corresponds with the biggest similarity value, such as C, D, E, F, G, A, or B.
3. Choose that chord text as the output text.

As a note, the above-mentioned similarity calculation and chord decision show that this study make use a template matching classification approach [19-21].

*Chord Database*

A chord database was created by combining seven reference coefficients of feature extraction. These seven reference coefficients reflect all of the chords used in this study, namely C, D, E, F, G, A, and B. The following is the methodology for creating the chord database.

1. Record ten samples of every chord (C, D, E, F, G, A, and B). These ten samples were chosen with the assumption that by recording ten samples, all samples variability would be acquired.
2. Perform feature extraction on all recorded samples. As illustrated in Fig. 1, this computation is executed utilizing normalization up to DCT processes.
3. Using the formula below to calculate the sample average for every chord.

$$R_v = \frac{1}{10}\sum_{m=1}^{10} P_{v,m} \tag{5}$$

   where $v$ is a chord (C, D, E, F, G, A, or B). $\{\mathbf{P}_{v,k} \mid 1 \le k \le 10\}$ are ten arrays of $v$ chord coefficients, and $\mathbf{R}_v$ is an array of $v$ chord reference coefficients..
4. Stored the sample averages $\mathbf{R}_C$, $\mathbf{R}_D$, $\mathbf{R}_E$, $\mathbf{R}_F$, $\mathbf{R}_G$, $\mathbf{R}_A$, and $\mathbf{R}_B$ into a chord database.

## Test Chords

There were a total of 140 test chords. These chords were obtained by recording the other 20 samples of every chord (C, D, E, F, G, A, and B).

## Performance Testing and Result

The performance testing was carried out by using the above-mentioned test chords. During testing, three parameters were evaluated simultaneously. They are the values of the lowest mel filter frequency, the number of mel filters, and the shape factor of Kaiser window. As a note, the lowest mel filter frequency is the mel bandpass filter's lowest center frequency, and the number of mel filters is the number of mel filters in the mel filter bank. The lowest mel filter frequencies used were 40, 45, 50, 55, 60, 65, 70, and 75 Hz. The number of mel filters used were 10, 15, 20, 25, 30, 35, 40, and 45 filters. The shape factor values used were 1-8. During performance testing, only a range of 1-8 coefficients of feature extraction were used. The reason for choosing this range is conformed with the purpose of this study, namely to evaluate the number of these coefficients smaller than eight in a chord recognition system.

The performance result is shown in Table 1. This result is the best performance result. It was obtained by using the following the best parameters: shape factor ($\beta$) of 5, the lowest mel filter frequency of 60 Hz, and the number of mel filters of 35 filters. As a note, the accuracy was computed by dividing the correctly recognized chords by the total number of test chords (140 chords).

**TABLE 1.** The best performance result

| **Number of coefficients of feature extraction (coefficients)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| Accuracy (%) | 14.29 | 50.00 | 87.86 | **92.14** | 92.14 | 92.14 | 92.14 | 91.43 |

## DISCUSSIONS

From the standpoint of the number of coefficients of feature extraction, as indicated in Table 1, as the number of these coefficients gets larger, so does the accuracy. Essentially, as the number of these coefficients gets larger, so does the feature extraction space dimension. This occurrence will make it simpler to discriminate between the pattern of one class with other classes. This simpler discrimination will eventually lead to greater accuracy.

As indicated in Table 1, the best performance is four coefficients of feature extraction, since it is the lowest number of coefficients that gives the highest accuracy. On the other hand, by using only four coefficients, the chord recognition system can give accuracy up to 92.14%. If we compare to another feature extraction method that is based on segment averaging [7][8], if we use only four coefficients, they can only give accuracy up to 70.71% and 82.86%, respectively. Thus, it can be said that if we use only four coefficients, the studied MFCC with Kaiser windowing is the most efficient feature extraction if we take into account accuracy above 90%.

The comparison of the performance of the studied feature extraction method with several other feature extraction methods that is shown in Table 2. As indicated in Table 2, if we only take into account accuracy above 90%, the studied feature extraction method is the most efficient one. It only needs four coefficients in order to achieve accuracy of up to 92.14%.

**TABLE 2.** The comparison of the performance of several feature extraction methods for guitar chord recognition

| **Feature Extraction Methods** | **Number of Coefficients** | **Accuracy (%)** | **Test Chords** |
|---|---|---|---|
| Improved PCP [3] | 12 | 95.83 | 192 test chords from 192 generated guitar chords |
| CRP (Chroma DCT-Reduced log Pitch) Enhanced PCP [2] | 12 | 99.96 | 4608 test chords from 576 generated guitar chords |
| Segment averaging with SHPS and logarithmic scaling [7] | 8 | 100 | 140 test chords from 140 recorded guitar chords |
| Segment averaging and subsampling [8] | 6 | 91.43 | 140 test chords from 140 recorded guitar chords |
| MFCC with Kaiser windowing (this study) | **4** | **92.14** | 140 test chords from 140 recorded guitar chords |

Note: (1) The number of coefficients is refers to the number of coefficients of feature extraction.; (2) The table only shows the lowest number of coefficients, which can give an accuracy of above 90%.

## CONCLUSION AND FUTURE STUDY

This study proposes three parameters that can be evaluated simultaneously in an MFCC with Kaiser windowing in a guitar chord recognition. The three parameters, namely the lowest mel filter frequency and the number of mel filters in the mel filter bank, and also the shape factor of the Kaiser window. Based on experiments that have been carried out using 140 test chords, the best result can be obtained by using four coefficients of feature extraction, since it could achieve an accuracy of up to 92.14%. For future study, other methods besides MFCC with Kaiser windowing can be studied. In this case, by using only four coefficients, it could give an accuracy of above 92.14%.

## ACKNOWLEDGEMENT

This study has been supported by the Center of Intelligent Technology Study of Sanata Dharma University, Yogyakarta.

## REFERENCES


1. T. Fujishima, "Realtime Chord Recognition of Musical Sound: A System Using Common Lisp Music," in *ICMC Proceedings*, vol. 9, no. 6 (1999), pp. 464–467.
2. P. Rajpurkar, B. Girardeau, and T. Migimatsu, Stanford Undergrad. Res. J. **15**, 36–40 (2015).
3. K. Ma, "Automatic Chord Recognition," Personal Project, 2016. http://pages.cs.wisc.edu/~kma/projects.html (accessed Jul. 12, 2022).
4. E. Demirel, B. Bozkurt, and X. Serra, "Automatic chord-scale recognition using harmonic pitch class profiles," in *Proc. Sound Music Comput. Conf.* (2019), pp. 72–79.
5. K. S. Rao and A. K. Vuppala, *Speech Processing in Mobile Environments* (Springer International Publishing, New York, 2014).
6. S. Sen, A. Dutta, and N. Dey, Audio Processing and Speech Recognition Concepts, Techniques and Research Overviews (Springer, Singapore, 2019).
7. L. Sumarno, Int. J. Electr. Eng. Informatics **10**, no. 4, 753–764 (2018).
8. L. Sumarno, "Chord Recognition using FFT Based Segment Averaging and Subsampling Feature Extraction," in *2020 8th International Conference on Information and Communication Technology, ICoICT 2020* (2020), pp. 465–469.
9. L. Ivanov and J. Dunn, "Automatic Identification of Guitar Types from Prerecorded Audio," in *33rd FLAIRS Conference 2020* (2020), pp. 308–311.
10. D. A. Talavera, E. S. C. Nase, L. D. Pancho, and A. L. Ilao, J. Adv. Inf. Technol. **11**, no. 3, 149–154 (2020).
11. K. Vaca, M. M. Jefferies, and X. Yang, "An Open Audio Processing Platform with Zync FPGA," in *2019 22nd IEEE Int. Symp. Meas. Control Robot. Robot. Benefit Humanit. ISMCR 2019* (2019), pp. D1-2-1-D1-2–6.
12. K. Vaca, A. Gajjar, and X. Yang, "Real-Time Automatic Music Transcription (AMT) with Zync FPGA," in *Proc. IEEE Comput. Soc. Annu. Symp. VLSI, ISVLSI*, vol. 2019-July (2019), pp. 378–384.
13. L. Tan and J. Jiang, Digital Signal Processing Fundamentals and Applications, 3rd ed. (Elsevier Inc., Oxford , 2019).
14. O. K. Hamid, J. Information, Commun. Intell. Syst. **4**, no. 5, 87–94 (2018).
15. C. Asmita, T. Savitha, and K. Upadhya, Int. J. Innov. Res. Adv. Eng. **1**, no. 10. 2349–2163 (2014).
16. H. Rakshit and M. A. Ullah, "A comparative study on window functions for designing efficient FIR filter," in *2014 9th Int. Forum Strateg. Technol. IFOST 2014*, no. July (2014), pp. 91–96.
17. S. Sohangir and D. Wang, J. Big Data **4**, no. 1 (2017).
18. M. Voelsen, D. L. Torres, R. Q. Feitosa, F. Rottensteiner, and C. Heipke, ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci. **5**, no. 3, 181–189 (2021).
19. A. K. Jain, R. P. W. Duin, and J. Mao, IEEE Trans. Pattern Anal. Mach. Intell. **22**, no. 1, 4–37 (2000).
20. A. Massari, R. W. Clayton, and M. Kohler, Bull. Seismol. Soc. Am. **108**, no. 5, 2556–2564 (2018).
21. H. U. Zhi-Qiang, Z. Jia-Qi, W. Xin, L. I. U. Zi-Wei, and L. I. U. Yong, "Improved algorithm of DTW in speech recognition," in *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 563, no. 5 (2019).