

**MAKALAH ILMIAH
PROSIDING SEMINAR INTERNASIONAL
TERINDEKS SCOPUS**

**The 42th Annual International Conference of the IEEE
Engineering in Medicine and Biology Society (EMBC)
2020**



Judul:

Subject-independent Classification on Brain-Computer Interface
using Autonomous Deep Learning for finger movement recognition

disusun oleh:

Khairul Anam, Saiful Bukhori, Faruq Sandi Hanggara, and Mahardhika Pratama

**JURUSAN TEKNIK ELEKTRO
FAKULTAS TEKNIK
UNIVERSITAS JEMBER
2020**

Diseminarkan Secara Virtual



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Carolyn McGregor AM, Ontario Tech University

Atam Dhawan, NJIT

Program Chairs

Benoit Gosselin, Université Laval

Joaquin Azpiroz Leehan, Universidad Autonoma Metropolitana

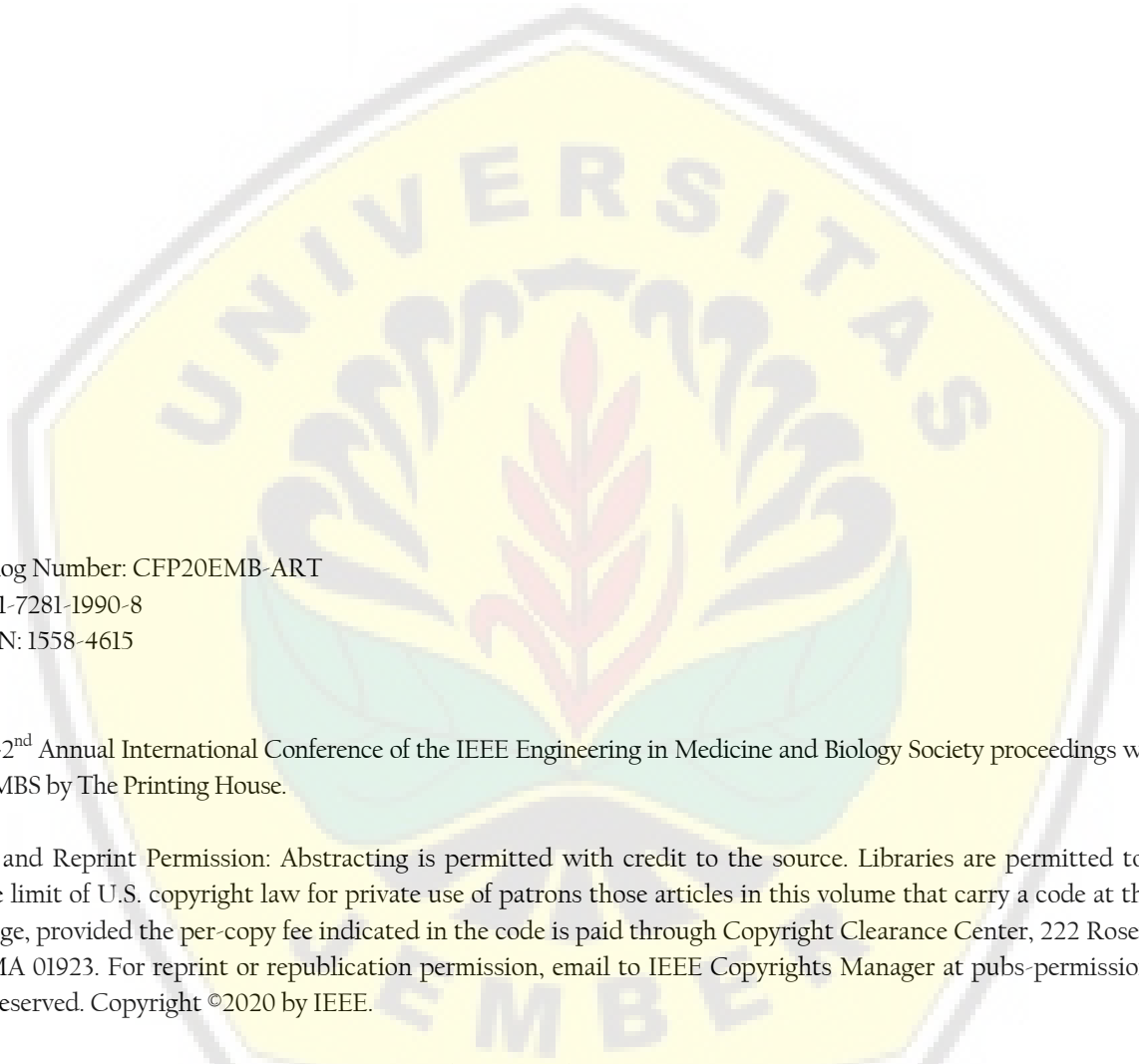
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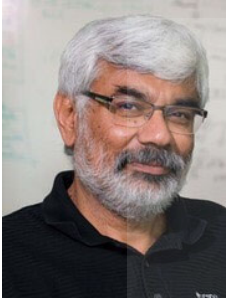
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President's Welcome Message



Dear Members of the EMBS Family,

I want to extend a warm welcome to all to The EMBC 2020 Virtual Academy!

Our plan was to meet in person in the beautiful city of Montreal enjoying summer outdoor cafes with music between the events of the Conference. Alas, that has turned out not possible due to the pandemic. We are providing a true test of virtual communication technologies and our resilience to hardships. The theme for this year's Conference, "Enabling Innovative Technologies for Global Healthcare", could not be more appropriate. The pandemic mandates the development of innovative technologies and as a world community we need to come together to fight this unforeseen monster.

The past six months have witnessed the emergence of the human spirit and willingness to improvise. Engineering has come to the forefront in developing personal protective equipment, from facemasks to ventilators. We have witnessed the emergence of global pandemic data and the engineering models to help create analytical and predictive scenarios. Biotechnology has already paved the way for developing vaccines and when validated the mass production at low cost will warrant even newer technologies. Our Society can play an important role in aiding this process.

EMBC 2020 offers an exciting series of sessions and speakers. The keynote talks are immensely contextual. Testing for cancer in developing countries is a huge challenge and Dr. Cremer who is the founding president of the Basic Health International will highlight the challenges in her EMBC keynote. Dr. Ramanujam is a pioneer bringing innovative strategies for women's health in developing countries. Her innovative scope for cervical cancer has already saved thousands of lives across continents. We have as a keynote speaker a renaissance engineer Dr. Denison who has pioneered technologies at the interface of measurement and computation. What is more important than gadgets to improve Global Health? Dr. Ansermino, a clinician-scholar who will discuss innovative technologies that improve the lives of millions across the globe. The themes for EMBC 2020 are featured by star speakers who bring the latest developments in the field. EMBC always features outstanding special sessions. Young Professionals and Women in Engineering are an inspiration for the entire Society and these sessions will cap the Conference.

I realize that unlike an in person meeting, we will have members signing in from all possible time zones across the globe. To facilitate visiting the meeting, EMBC 2020 offers asynchronous views of the sessions providing many opportunities to interact. I welcome you to this experiment that could become a harbinger for the future.

I sincerely hope that you will enjoy EMBC 2020 and hope that engineers working in medicine and biology will help overcome the pandemic for us to meet in person in the enchanting city of Guadalajara.

A handwritten signature in purple ink that reads "Shankar Subramaniam".

Shankar Subramaniam
EMBS President, 2019-2020



Welcome Message from Organizing Committee

Bienvenue!

Welcome to the 42nd Annual International Conferences of the IEEE Engineering in Medicine and Biology Society (EMBC'20) in conjunction with the 43rd Annual Conference of the Canadian Medical and Biological Engineering Society (CMBES'20). We are glad to see you joining this virtual edition of the IEEE Engineering in Medicine and Biology Conference this year. Preparations for the conference began more than four years ago and the work during the last 12 months have been a challenge due to COVID-19, however, we managed to service EMBS's members to the best of our ability with the means that we had. The unifying theme of the present edition of EMBC, "Enabling Innovative Technologies for Global Healthcare", highlights what Canada values as a country with a strong focus on giving higher priorities to well-being and the best quality of life.

A carefully tailored program was achieved by a selection of outstanding plenary, keynote and tutorial speakers from academic, clinical and industrial backgrounds and various IEEE regions. Significant care and consideration was given to equality, diversity and inclusion as well. This top-quality program would not have been achievable without the large number of contributions submitted by authors from over 58 countries. We graciously thank everyone who contributed to make EMBC'20 a very successful event despite the unfortunate circumstances of 2020. You will find the regular program integrated with workshops, mini symposia, and special sessions, in addition to a great collection of Video Presentations created by our Authors. A special session along with a group of papers have been scheduled from significant contributions addressing COVID-19 as well. Please make use of the online tools for providing comments, networking and socializing.

Montreal is one of the major industrial hubs dealing with healthcare and wellness fields. In addition, current coronavirus events increase the expectation on developing new technologies related to monitoring and treatments. Consequently, biomedical engineering fields are attracting attention, and will see a boost of support from the public, governments, and funding agencies to accelerate solutions to preventive and supportive healthcare.

We would like to take this opportunity to thank the Program Committee and the EMB Conference Editorial Board who diligently worked to create an interesting and dynamic program for the conference. We would like to thank the EMBS Executive Office, for their significant efforts to deal with the virtualization of this conference and for keeping us on schedule.

We hope that you will find IEEE EMBC 2020 to be a source of innovation and fruitful exchanges, and we encourage you to seize this opportunity to meet your colleagues online and renew your social network. We sincerely hope that this EMBC edition will enrich you with new ideas and that you will enjoy your online participation.

Merci beaucoup! Thank you very much!

Mohamad Sawan, Carolyn McGregor AM, Atam Dhawan
Conference Chairs

Benoit Gosselin, Joaquin Azpiroz Leehan, Olaf Doessel, Dominique Durand
Program Chairs

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The 42nd Annual International Conference of the
IEEE Engineering in Medicine and Biology Society
July 20 - 24



"Enabling Innovative Technologies
for Global Healthcare"



Hey there,

The IEEE Engineering in Medicine and Biology Society, and its partner, the Canadian Medical and Biological Engineering Society, thank you for registering to participate in the 42nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society in conjunction with the 43rd Annual Conference of the Canadian Medical and Biological Engineering Society, to be delivered Virtually on the New EMBS Virtual Academy!

The conference will include:

- 1600+ On-Demand Pre-Recorded Author Presentations of Research
- 43 On-Demand Pre-Recorded Mini-Symposium & Special Session Presentations
- A Live Web Cast Welcome Ceremony & Awards Presentation
- 20 Live Webcast Talks & Sessions, with live Q&A, including Prominent Speakers highlighting a wide range of Hot Topics in Biomedical Engineering
- Virtual Exhibit Hall to engage with supporting organizations of the conference

What if I have a question for a speaker in a pre-recorded session?

All Pre-recorded sessions will have running discussion boards where you can engage directly with the session contributor to network or post questions.

What if I miss a live session?

All live sessions will be made available for on demand viewing approximately 30 minutes after the live session concludes.

Contributing Research Papers

All contributed papers and video presentations will be available for on-demand viewing, and contain a running discussion board for questions and/or comments from participants. Authors and all participants are encouraged to engage closely in these discussion boards, mainly during the conference's main scheduled dates of July 20 – 24, 2020, and respond to any questions that may be posed by participants and colleagues. As a reminder, where all author presentations were pre-recorded, there will be no live presentations of author papers.

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Registered for a Pre-Conference Workshop?

Pre Conference workshops will take place on either Friday, Saturday, or Sunday, as scheduled, and will be accessible on the Virtual Academy, to those who have registered a pre-conference workshop. Registered workshop participants will also receive a reminder message prior to your workshops start date.

Not registered for a workshop? There is still time to [modify your registration](#) to add a pre-conference workshop. Don't miss out!

Virtual Exhibit Hall

The conference is fortunate to have many sponsors and exhibitors continue with us on this virtual journey, and we greatly appreciate their participation this year. Please visit the conference's virtual exhibit hall to view content and engage with these critical biomedical organizations.

Accessing the Virtual Conference:

All who are registered will be provided access to the virtual platform through August 19, 2020, a full 30 days!

To access the EMBS Virtual Academy, you must navigate your supported web browser to <https://academy.embs.org/> As this will be your first time logging into the EMBS Virtual Academy, please follow the steps below for your initial login:

- On the EMBS Virtual Academy Home page select “Direct Access Request” in the upper right hand corner of the landing page
- There you will be prompted to enter your registration email address [ExampleContactEmailAddress]; *the email address you used to register for the conference*
- You will be sent an email from support@multiregistration.com ; *be sure to check your spam or junk folders in case the email is blocked – please note, you will only receive this email where the email address is formally registered for the conference.*
- The email will contain a link which will provide access to the virtual platform and all available content the conference has to offer you!

Should you require technical support during the conference please contact support@multilearning.com

We thank you for your support of EMBC 2020 during these difficult times for us all, and are confident that you will enjoy this virtual conference experience!

Be safe and well!

EMBS Conference Operations

Program at a Glance

Friday, July 17, 2020 (Pre-Conference Workshops- Registration Required)		
Student and Young Professionals Global Meeting	8:30am	9:30am
Women in Engineering	10:00am	12:00pm
Brain-Machine Interfaces (BMI) to Machine-Brain Interfaces (MBI): The Next Frontier	1:30pm	5:30pm
Saturday, July 18, 2020(Pre-Conference Workshops- Registration Required)		
Brain-Computer Interface Neurotechnology for Control, Rehabilitation, Brain Assessment and Cortical Function Mapping	8:30am	12:30pm
Hyper-Adaptability for Overcoming Body-Brain Dysfunction: Integrated Empirical and System Theoretical Approaches	8:30am	12:30pm
Break	12:30pm	1:30pm
Open Challenges in Deep Learning for Biomedical Image Analysis	1:30pm	5:30pm
Advances in Wearable Technology and Biomedical Devices: Opportunities and Challenges	1:30pm	5:30pm
Sunday, July 19, 2020(Pre-Conference Workshop- Registration Required)		
Feature Engineering and Computational Intelligence in Wearable Health Monitoring	8:30am	12:30pm
Monday, July 20, 2020		
Opening Ceremony & Welcome	8:30am	10am
Break	10am	10:30am
Last Call Speaker: Andrea Webb	10:30am	12pm
Break	12pm	12:30pm
Keynote Speaker Theme 2 Biomedical Imaging and Image Processing - Tal Arbel	12:30pm	2pm
Break	2pm	2:30pm
Keynote Speaker Theme 1 Biomedical Signal Processing - Pierre-Alexandre Fournier	2:30pm	4pm
Break	4pm	4:30pm
Last Call Speaker: Christopher Khoury	4:30pm	6pm
Tuesday, July 21, 2020		
Theme 6 Keynote Speaker: Nitish Thakor	8:30am	10am
Break	10am	10:30am
Keynote Speaker: Nimmi Ramanujam	10:30am	12pm
Break	12pm	12:30pm
Keynote Speaker Theme 4 Computational Systems, Modeling and Simulation in Medicine, Multiscale Modeling - Joelle Pineau	12:30pm	2pm
Break	2pm	2:30pm
Keynote Speaker Theme 3 Micro/Nano-bioengineering Cellular/Tissue Engineering & Biomaterials- Maryam Tabrizian	2:30pm	4pm
Wednesday, July 22, 2020		
Keynote Speaker Theme 7 Biomedical Sensors and Wearable Systems - Sandro Carrara	8:30am	10am
Break	10am	10:30am
Keynote Speaker: Miriam Cremer	10:30am	12pm
Break	12pm	12:30pm
Addressing Clinical IoT Interoperability and Security Challenges Globally Part I	12:30pm	2pm
Break	2pm	2:30pm
Addressing Clinical IoT Interoperability and Security Challenges Globally Part II	2:30pm	4pm
Break	4pm	4:30pm
Last Call Speaker : Alan M. Weinstein	4:30pm	6pm
Thursday, July 23, 2020		
Keynote Speaker Theme 9 Therapeutic & Diagnostic Systems and Technologies - Thomas Stieglitz	8:30am	10am
Break	10am	10:30am
Keynote Speaker: John Ansermino	10:30am	12pm
Break	12pm	12:30pm
Keynote Speaker Theme 5 Cardiovascular and Respiratory Systems Engineering - Zorina Galis	12:30pm	2pm
Break	2pm	2:30pm
Keynote Speaker Theme 8 Biorobotics and Biomechanics - Sylvain Martel	2:30pm	4pm
Break	4pm	4:30pm
Special Session: Wireless Medical Devices Going into the 5G World: New Use Cases, Practical Issues, and Challenges	4:30pm	6pm
Friday, July 24, 2020		
Keynote Speaker Theme 10 Biomedical & Health Informatics - Adrian Schauer	8:30am	10am
Break	10am	10:30am
Keynote Speaker Tim Denison	10:30am	12pm
Break	12pm	12:30pm
OPEN	12:30pm	2pm
Break	2pm	2:30pm
Keynote Speaker Theme 12 Translational Engineering for Healthcare Innovation and Commercialization - Theodore Papagiannis	2:30pm	4pm
Break	4pm	4:30pm
Enabling Innovative Technologies for Global Healthcare: Round Table on COVID-19	4:30pm	6pm
*All Times are EDT UTC/GMT -4 Hours		
**All Sessions will be available On Demand Upon Completion		
***On Demand Sessions will be available to all registrants through August 19, 2020		

Digital Repository Universitas Jember Special Sessions

**Early-Career Researcher Series: Transitioning from a
Graduate Student to a Professional**

Organizer: Aishwarya Bandla

**Enabling Innovative Technologies for
Global Healthcare: Round Table on COVID-19**

Organizer: Colin Brennan

Special Session: Clinical Engineering Initiatives in Canada

Organizer: Michael Capuano

NIH Grantsmanship Session

Organizer: Kee Forbes

**Addressing Clinical IoT Interoperability and Security
Challenges Globally (Part I & II)**

Organizer: Florence Hudson

Demonstrating the Value of In-House Clinical Engineering Service

Organizer: Andrew Ibey

Biomedical Engineering in Latin America – Perspectives towards EMBC 2021

Organizer: Roberto Lavarello

Starting Your Own Company: Part I

Organizer: Dorin Panescu

Starting Your Own Company: Part II

Organizer: Dorin Panescu

CMBES Clinical Engineering Cross Canada Check-Up

Organizer: Martin Poulin

**Wireless Medical Devices Going into the 5G World:
New Use Cases, Practical Issues, and Challenges**

Organizer: Donald Witters

Digital Repository Universitas Jember Minisymposia

MINI SYMPOSIA TITLE	ORGANIZERS
The Evolving Science and Engineering of Tumor Treating Fields: -Part I	Ze'ev Bomzon
The Evolving Science and Engineering of Tumor Treating Fields: -Part II	Ze'ev Bomzon
Emerging Biomedical Engineering Technologies in Veterinary Medicine	Nadja Bressan
Methods for Trustworthy and Reliable In-the-Wild EEG Recordings	Alexander James Casson
Artificial Vision: Latest Progress in Retinal Prosthetics	Leanne LH Chan
Recent Advances in Sensory Neuroprostheses - Part II	Hamid Charkhkar
Engineering and Medicine in Extreme Environments - Part I	Tobias Cibis
Engineering and Medicine in Extreme Environments	Tobias Cibis
Activity Trackers in Healthcare: Signal Processing and Machine Learning for Monitoring and Detecting Health Conditions	Kajal Claypool
Time-Series Modelling of Physiology: Inference, Implementation, and Interpretability	Glen Wright Colopy
Low Intensity Focused Ultrasound: Engineering Developments and Therapeutic Applications	Allegra Conti
Mobile Point-of-Care Diagnostic and Health Monitoring Devices	Partha Sarati Das
Computational Models of Neuromodulation	Socrates Dokos
Implantable Wireless System for Neural Recording and Brain Stimulation	Gabriel Gagnon-Turcotte
Recent Advances in Sensory Neuroprostheses - Part I	Emily Graczyk
Emerging Biophotonic Applications Based On, or Conjoined with OCT Technologies	Boris Gramatikov
Brain-Computer Interfaces for Neuromodulation, Language Decoding and High-Gamma Mapping	Christoph Guger
Recent Advances on Cuff-Less Blood Pressure Measurement II	Jin-Oh Hahn
New Developments in Sleep Bioengineering: 1. Detection and Analysis of Patterns in Disturbed Sleep	Michael Khoo
New Developments in Sleep Bioengineering: 2. Novel Diagnostic Markers for Sleep Apnea	Michael Khoo

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MINI SYMPOSIA TITLE	ORGANIZERS
New Developments in Sleep Bioengineering: 3. A Deeper Dive into New Clinical Findings in Sleep-Disordered Breathing	Michael Khoo
Advanced Photoacoustic and Optical Imaging	Chulhong Kim
Emerging Neural Technologies for Neuroprosthetic Hand	Ning Lan
Bio-Nano-Micro Systems in Biomedical/Clinical Applications	Kin Fong Lei
Telemedicine Enabling Person-Centered Telecare	Natividad Martinez Madrid
Brain-Machine Interface: From Neurophysiology to Clinical Applications	Matija Milosevic
Recent Advances on Cuff-Less Blood Pressure Measurement I	Ramakrishna Mukkamala
Current Trends in Bioelectronic Systems to Interface with the Human Nervous System	Hangue Park
Microwaves in Biomedical Applications - Part I: Breast Cancer Detection and Monitoring	Milica Popovic
Microwaves in Biomedical Applications - Part II: Diverse Sensing Applications	Milica Popovic
Implantable BCI and Clinical Applications: Functional Compensation and Rehabilitation for Motor Impairment	Fabien Sauter-Starace
Artificial Intelligence in Rehabilitation	Ervin Sejdic
Methodological and Technical Advances in Fetal/newborn Heart Rate Monitoring	Maria G. Signorini
Data Analytics in the Wild: Emerging Wearable Inertial Sensors and Egocentric Cameras for Prevention and Rehabilitation	James Yungjen Tung
Augmented Neural Prostheses	James Weiland
Noninvasive Fractional Flow Reserve from Computed Tomography Coronary Angiography: Challenges and Opportunities	Liang Zhong

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Conference Editorial Board EMBC 2020 Virtual Academy

In these unprecedented times, in the midst of uncertainty, isolation, limitation of movement, and unfortunately for some, pain and loss, like never before I would like to sincerely thank all the members of the Conference Editorial Board. Despite the distance and the slow but inevitable realization that, for the first time, we would not have the chance to see our work unwind in a physical environment, we never worked so well together as a team and in perfect timing to finalize the EMBC 2020 Conference Program.

There were 2,378 submissions overall. 1,946 of these were full-contributed manuscripts that were part of our rigorous peer-review process. These papers were reviewed with a minimum of two reviewers per paper. Theme Editors made initial “accept/reject” decisions and created a draft scientific program for each Theme. 198 of these papers were nominated for the Student Paper Competition, further reviewed by an Ad-Hoc Committee.

We received 18 Workshops, 17 Special Session, and 51 Minisymposia proposals, carefully reviewed by a separate review panel selected by the Program Committee. This year, we also organized a late breaking submission on COVID-19 investigations related to our themes, resulting in 18 1-page poster papers, also reviewed by a special panel.

Lastly, there were 326 Research Poster submissions. These were reviewed by a special team of Associate Editors, handpicked by the local organizers and the EMB Technical Committees. I thank all these individuals for their time as they rapidly reviewed them. 221 of these submissions made it to the final program.

As always, we maintained the highest quality of papers being selected, each with ratings and feedback given to authors from reviewers. The continued dedication and commitment of Editors, Associate Editors and Reviewers, makes this Annual Conference an active and vibrant community of science. So please let me again warmly thank all the members of the Editorial Board, listed below. It has been a privilege and an honour to be part of such a fine community of esteemed scientists. Despite the circumstances, even if just from a computer screen and not in beautiful Montreal, I believe the passion and dedication of our work will transpire one session at a time and, on your behalf, I wish to invite all the EMBC 2020 participants to enjoy this unique online event!

Riccardo Barbieri, Editor in Chief - Conference Editorial Board

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Co-Editor: Marius George Linguraru
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Theme 10. Biomedical & Health Informatics

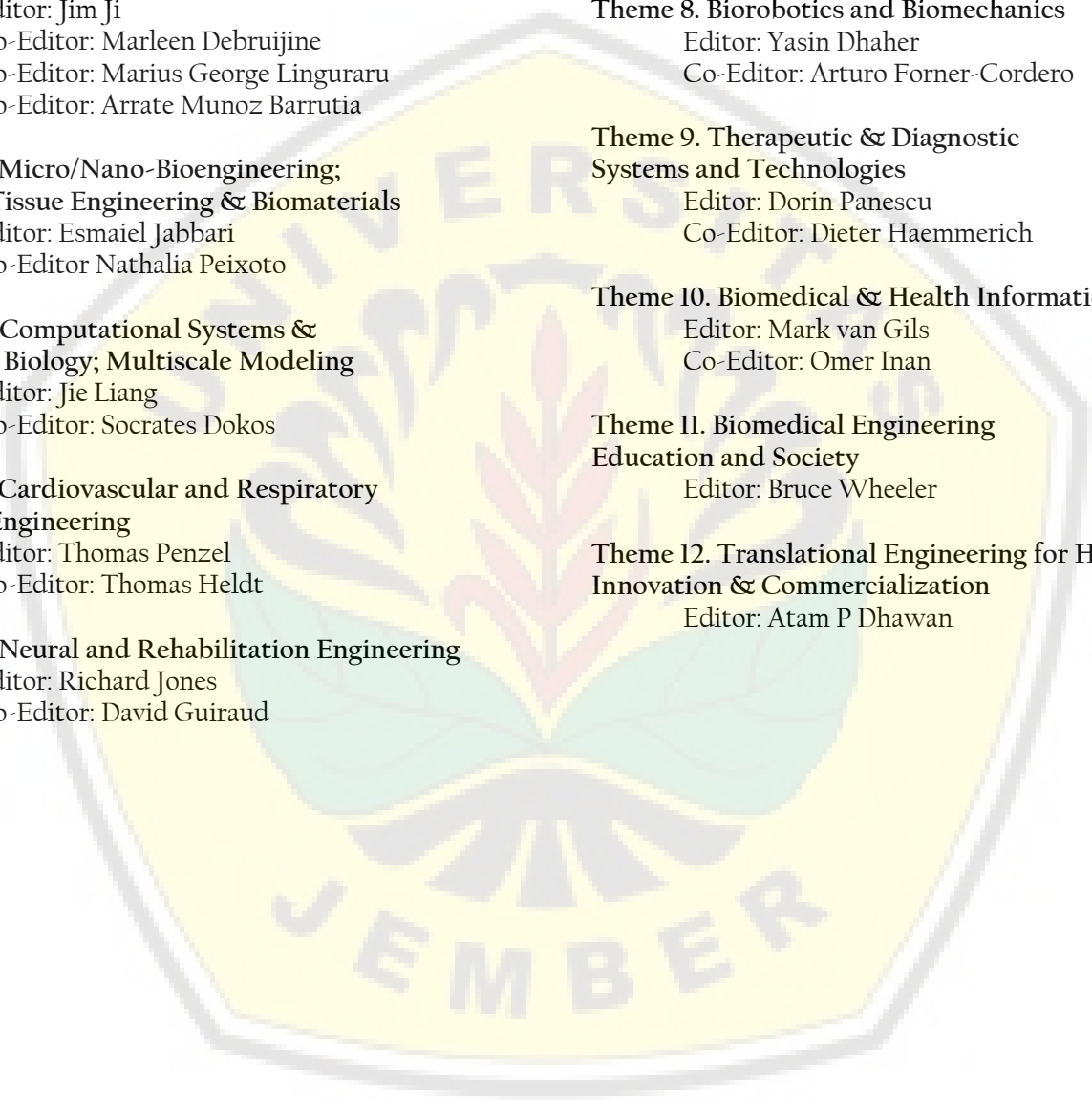
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Co-Editor: Omer Inan

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Education and Society**

Editor: Bruce Wheeler

**Theme 12. Translational Engineering for Healthcare
Innovation & Commercialization**

Editor: Atam P Dhawan



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Boudaoud, Sofiane
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Humeau-Heurtier, Anne
Kahya, Yasemin P.
Laguna, Pablo
Magenes, Giovanni
Michmizos, Konstantinos
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Signorini, Maria G.
Song, Dong
Sornmo, Leif
Valenza, Gaetano
Vanrumste, Bart
Voss, Andreas
Westwick, David
Yamamoto, Yoshiharu
Yana, Kazuo

Theme 02. Biomedical Imaging and Image Processing

Alic, Lejla
Anastasio, Mark
Chan, Kevin C.
Ding, Lei
Du, Yiping
Duan, Qi
Fenster, Aaron
Gonzalez Ballester, Miguel Angel
Gu, Xuejun
Ji, Jim Xiuquan
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Munoz-Barrutia, Arrate
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Rizzo, Giovanna
Sidky, Emil
Sikdar, Siddhartha
Staib, Lawrence H.
Suzuki, Kenji
Toschi, Nicola
Vinegoni, Claudio
Ying, Leslie

Theme 03. Micro/Nano- Bioengineering; Cellular/Tissue Engineering & Biomaterials

Almasri, Mahmoud
Hamad, Eyad
Jabbari, Esmail
Lee, Hyunjoo Jenny
Lord, Megan
Peixoto, Nathalia
Raje, Manasi
Siu, Vince
Wu, Hung-Wei

Theme 04. Computational Systems & Synthetic Biology; Multiscale Modeling

Dai, Yang
Dokos, Socrates
Lu, Ting
May, Elebeoba
Xia, Yu
Zhang, Jinfeng

Theme 05. Cardiovascular and Respiratory Systems Engineering

Armoundas, Antonis
Chbat, Nicolas W.
Di Rienzo, Marco
Heldt, Thomas
Jané, Raimon
Li, John K.-J.
Sugimachi, Masaru

Theme 06. Neural and Rehabilitation Engineering

Abbas, James
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Astolfi, Laura
Azevedo-Coste, Christine
Babiloni, Fabio
Besio, W. G.
Bianchi, Anna Maria
Chiappalone, Michela
Guiraud, David
James, Christopher
Jones, Richard D.
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Perreault, Eric
Petroff, Neil
Sahin, Mesut

Santacruz, Samantha R.
Stieglitz, Thomas
Strauss, Daniel J.
Suaning, Gregg
Tong, Shanbao
Wang, Yiwen
Weiland, James
Zouridakis, George

Theme 07. Biomedical Sensors and Wearable Systems

Almasri, Mahmoud
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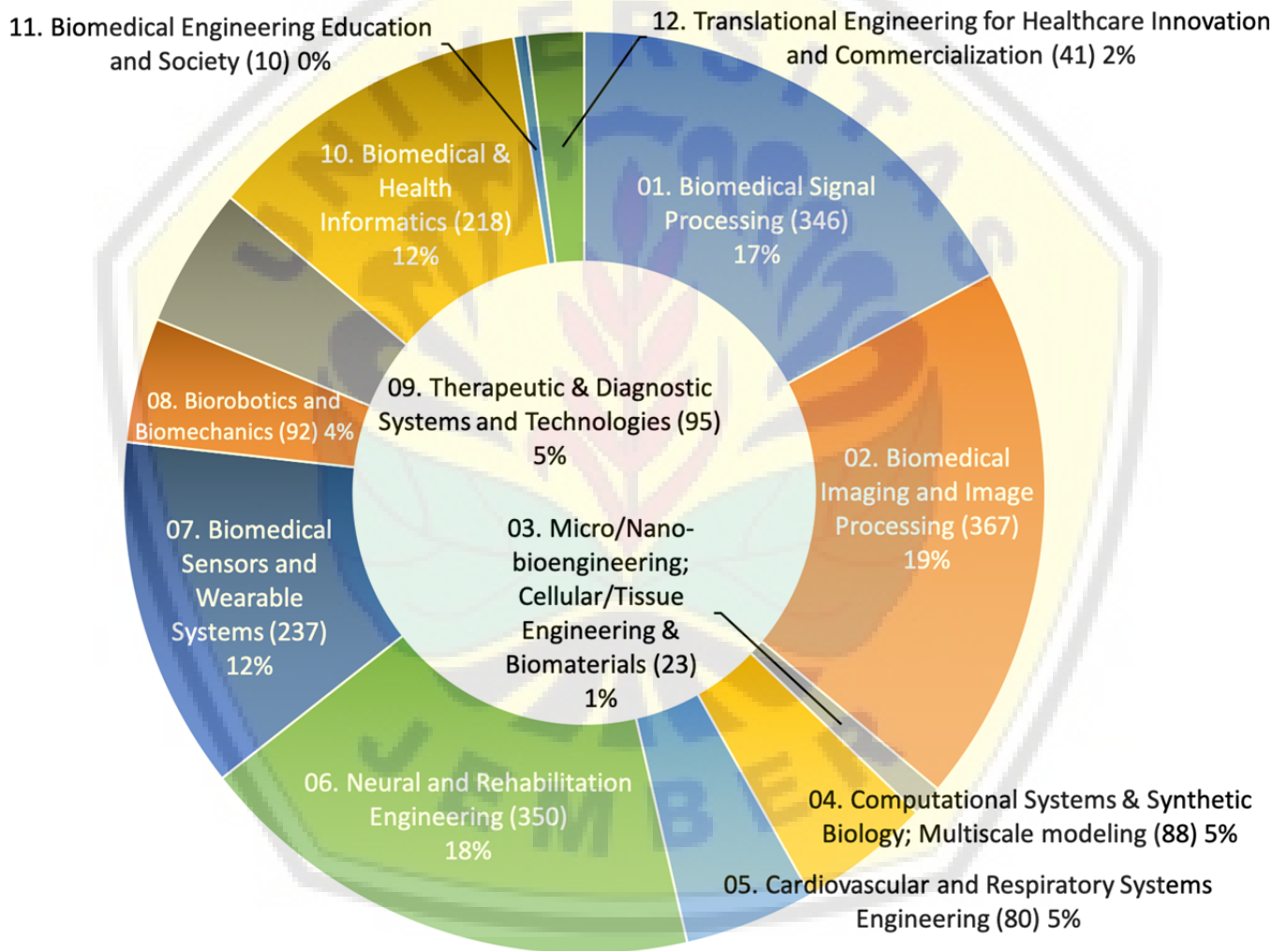
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Subject-independent Classification on Brain-Computer Interface using Autonomous Deep Learning for finger movement recognition

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Abstract— The degradation of the subject-independent classification on a brain-computer interface is a challenging issue. One method mostly taken to overcome this problem is by collecting as many subjects as possible and then training the system across all subjects. This article introduces streaming online learning called autonomous deep learning (ADL) to classify five individual fingers based on electroencephalography (EEG) signals to overcome the issue above. ADL is a deep learning architecture that can construct its structure by itself through streaming learning and adapt its structure to the changes occurring in the input. In this article, the input of ADL is a common spatial pattern (CSP) extracted from the EEG signal of healthy subjects. The experimental results on the subject-dependence classification across four subjects using 5-fold cross-validation show that that ADL achieved the classification accuracy of around 77%. This performance was excellent compared to a random forest (RF) and a convolutional neural network (CNN). They achieved accuracies of about 53% and 72%, respectively. On the subject-independent classification, ADL outperforms CNN by resulting stable accuracies for both training and testing, different from CNN that experience accuracy degradation to approximately 50%. These results imply that ADL is a promising machine learning in dealing with the issue in the subject-independent classification.

1. INTRODUCTION

The disability prevalence across various countries is quite a lot. For example, as many as five million Indian descendants have a disability [1]. Similarly, in Indonesia, around 2-3% of Indonesian citizens experience disabilities [2]. Many factors cause disability, one of which is amputation. The causes of amputations are various, such as diabetes, work accident or traffic accident. Various efforts need to take to restore their quality of life, especially disability on the hands. Losing hands becomes a severe problem for sufferers because the functionality of the hands in human life is very high.

One of the methods for the rehabilitation of amputees is by providing a prosthetic hand robot to replace lost hand functions. The challenge emerges how to design a control system for the robot in such a way the user feels that it is a part of the user's body. To produce such a control system, we have to design a control system that can predict the user desire based on human body signals such as electromyography (EMG).

Many studies have developed a pattern recognition system for hand movements based on EMG signals. However, EMG

signals for the hand movements cannot be obtained from patients who have amputations above the elbow. In addition, in patients who have very severe weakness of motor function (neuromuscular disease), the EMG signal cannot be recorded. The solution is to use another body signal, which is from a brain signal or electroencephalogram (EEG).

EEG signals are signals that are dynamic and non-stationary. As a result, the motion detection system is susceptible to changes in EEG signals such as fatigue, the humidity of the EEG electrode due to sweating, or a slight shift in the EEG electrode. Therefore, we need a detection system that is robust, sturdy, and not sensitive to changes or even little changes and also has an adaptive nature. One reason for the lack of solidity of the existing system is the use of learning machines that do not work online. In other words, various machine learnings such as artificial requirements network (ANN), support vector machine (SVM), k-nearest neighborhood (kNN), extreme learning machine (ELM), linear discriminant analysis (LDA) or other works in a batch learning system. In batch learning, the system is trained offline, and then the trained system is applied for testing. The problem is, due to the non-stationary property of the EEG signal, the data in offline learning is different from the data in real-time applications. Furthermore, the gap is getting more prominent when the system is implemented for a long period of time. Certainly, there will always be a recalibration of the system. Unfortunately, it will bore the patient.

An online learning system, or known as streaming learning, can be a solution to this problem. In this pattern recognition system, the system works directly, and at the same time, it is learning and adapting to the new environment. To some extent, the designed systems can also learn by themselves looking for the appropriate parameters to produce a sturdy system. This system is also known as autonomous machine learning or independent machine learning [3].

The success of deep learning in image processing inspires researchers to apply it to EEG signal processing [4]. The main advantage of deep learning is that it eliminates feature extraction stages because the feature extraction has become part of deep learning. However, the learning process is still in the form of batch learning or offline learning so it is less robust with changes. The use of online learning methods in deep learning is still in testing stages of the benchmark datasets. To the best of the author's knowledge, none of them have been applied to overcome the inherent problem of the EEG signal processing. This article is proposed to evaluate the

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performance of the online deep learning or so-called autonomous deep learning [5][3] to produce a robust EEG signal processing system.

This article will focus on the performance of the proposed system overcoming a robustness issue in degradation performance of the subject-independent classification especially on the EEG pattern recognition for finger movement. The common method to overcome the degradation performance in the subject-independence classification is by collecting as many subjects as possible [6][7]. This article takes different approaches by introducing the streaming deep learning called autonomous deep learning to classify five individual finger movements from EEG signal.

The rest of the paper is as follows. Section two presents the theoretical aspect of autonomous deep learning. Then, the section for material and method comes after it. Result and discussion and then the conclusion will end the presentation of this paper.

II. AUTONOMOUS DEEP LEARNING

Autonomous deep learning (ADL) is a supervised elastic deep neural network where the structure of hidden units and hidden layers can be constructed by itself in a long-life learning mechanism. The basic of ADL is the multi-layer perceptron (MLP) that consists of a first layer and multi intermediate layers. The former is the input feature while the latter is the hidden layers that have a connection to unique classifiers, as shown in Figure 1.

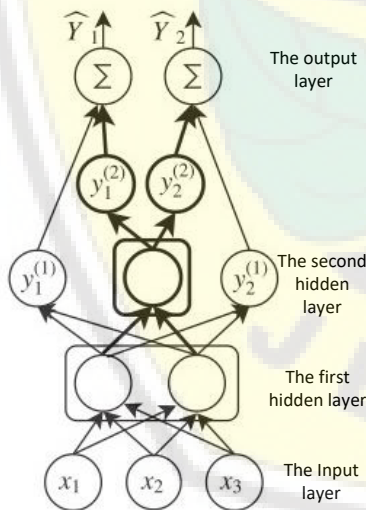


Figure 1 The Autonomous deep learning structure with two hidden layers

The equation of the ADL is as follow:

$$\hat{C} = \max_{o=1, \dots, m} \hat{Y}_o; \hat{Y} = \sum_{l=1}^L \beta^{(l)} \cdot y^{(l)} \quad (1)$$

where

$$y^{(l)} = \max(Ws^{(l)}h^{(l)} + bs^{(l)}) \forall l = 1, \dots, L \quad (2)$$

$$h^{(l)} = \sigma(Wh^{(l-1)} + b^{(l)}), h^{(1)} = X \quad (3)$$

In equation (1), $y^{(l)}$ is the multiclass probability, and L is the number of hidden layers. Meanwhile, in the equation (2) and (3), $W^{(l)} \in R^{K_l \times d}$ is the weight of the l -th hidden layer in which K_l and d is the number of hidden nodes and the number of input in the l -th hidden layer. Next, $b^{(l)} \in R^m$ is the bias of input layer and $\beta^{(l)}$ is the l -th hidden layer weight in which it is adjusted by reward and punishment factor.

ADL consists of two adaptations., i.e. the adaption of the network width and network depth. The first adaptation is governed by network significance (NS) method which creates a new hidden unit and prunes an inconsistent hidden unit. Meanwhile, the later adaption is driven by drift detection scenario (DDS) which creates and prune a hidden layer. In general, the learning mechanism of ADL is depicted in Figure 2.

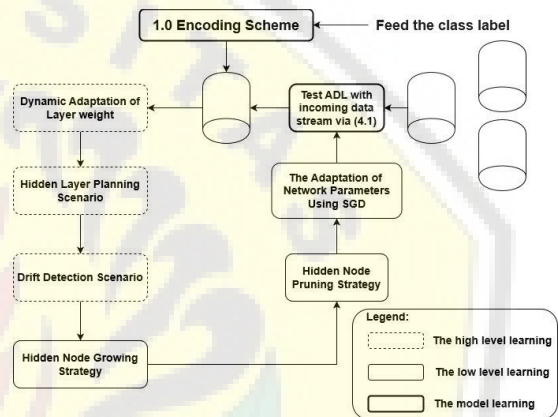


Figure 2. Autonomous Deep Learning [3]

III. METHOD

The experiments was carried out following the flow shown in Figure 3. The goal of the pattern recognition based on ADL is to decode five individual fingers from EEG signals. The dataset is EEG motor imagery for brain-computer interfaces obtained from [8]. The recording session parts we choose are five finger motion of five mental imagery types to discriminate finer movement imageries. All motor imageries are of a single hand.

The EEG montage consisted of 19 lead configured with the international 10-20 system, one bipolar lead X3 for data synchronization, and two ground leads A1 and A2. Although the dataset provides data of subject A to subject M, we only used four subjects {A, B, C, F} because their EEG signal recorded with both frequencies of 200Hz and 1000Hz.

We used four subjects A, B, C, and F at frequencies of 200Hz and 1000Hz. In this study, the feature of an EMG signal is the five components of the Common Spatial Pattern[9]. The windowing process uses a window length of 1 second and overlap by 0.75 seconds. The number of data for each subject A, B, C, and F are {4974, 4959, 5941, 4947} at 200Hz and {4853, 4962, 4856, 4944} at 1000Hz. We used 100 chunk data so there are around 40 streaming learning for each subject. Before being separated into several batches, the data is randomized first.



Figure 3 Computer-brain interface for movement predicting the hand movements

In this paper, we separated evaluation to subject dependent and subject independent to examine the robustness of the system. In subject-dependent, the model trained and tested with the dataset of each subject. On the other hand, subject-independent evaluation regards a subject dataset as test data and the others as train data. The model is trained with 5-fold cross-validations with shuffle, assuming that the comparison of training data and testing data that is 4: 1 is good enough for each fold to represent the aggregate data.

Comparison to other methods, random forest (RF) with 100 trees and convolutional neural network (CNN). As for CNN, it comprises 6 layers, 3 convolutional layers and 3 fully connected layers. The matrix size of the input is 28x28 while the feature size of the convolutional layers is 32x32, 64x64, and 64x64 for the first, second, and third layers, respectively.

IV. RESULT AND DISCUSSION

A. Subject-dependent classification

The subject dependent evaluation was performed on all subjects. Each new model is trained with some data from a subject and then tested with other data parts from the same subject. The experimental results are shown in Figure 4 and Figure 5.

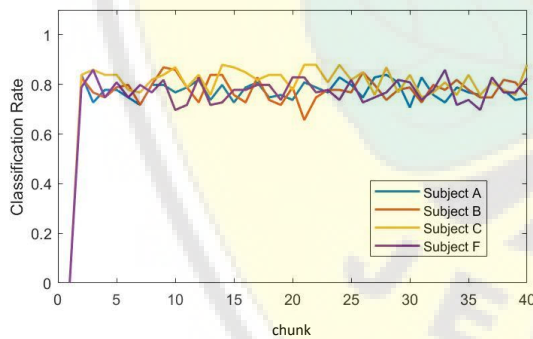


Figure 4. The average testing accuracy across four subjects using 5-cross validation on data with a frequency of 200 Hz

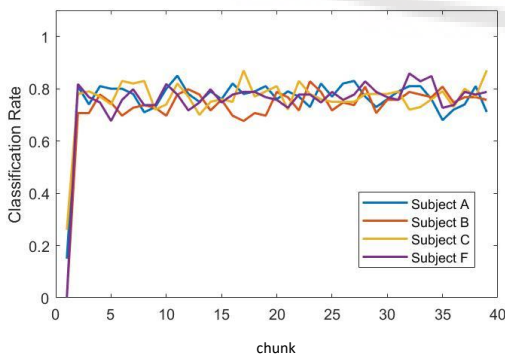


Figure 5. The average testing accuracy across four subjects using 5-cross validation on data with a frequency of 1000 Hz

Both figures indicate that the EEG pattern recognition based on ADL was able to predict the five individual fingers by the accuracy of around 70 to 80%. The performance of the proposed pattern recognition system is more standing up when we compare it with another deep learning method and one ensemble powerful classifier i.e. random forest (RF), as it can be seen from Table 1 to Table 4.

From these tables, we can see that the accuracy of ADL is the worst on the training stage. However, the testing accuracy of ADL is the best by the average accuracy of around 78% across four subjects compared to 53% and 72% for RF and CNN, respectively. In comparison to the work of [8], the ADL based pattern recognition based on EEG developed in this article achieves better results. This article employed the same datasets as those in [8] in which utilized support vector machine (SVM). Perhaps, this fact supports the advantage of ADL over other classifiers.

TABLE I. THE TRAINING ACCURACY OF ADL 5 CROSS-VALIDATION 200HZ DATA

SUBJECT	RF (%)		CNN (%)		ADL (%)	
	Mean	STD	Mean	STD	Mean	STD
A	100,00	0,00	99,95	0,01	77,57	0,22
B	100,00	0,00	99,91	0,07	77,73	0,16
C	100,00	0,00	99,90	0,07	81,76	0,31
F	100,00	0,00	99,93	0,03	78,05	0,20
AVERAGE	100,00	0,00	99,92	0,05	78,78	0,22

TABLE II. THE TESTING ACCURACY OF ADL 5 CROSS-VALIDATION 200HZ DATA

SUBJECT	RF (%)		CNN (%)		ADL (%)	
	Mean	STD	Mean	STD	Mean	STD
A	54,63	0,71	71,28	0,69	77,46	0,91
B	50,91	0,52	74,92	0,49	77,82	0,60
C	55,56	0,60	70,67	0,76	81,62	1,06
F	54,11	0,58	76,86	0,76	78,13	0,82
AVERAGE	53,80	0,60	73,43	0,67	78,76	0,85

TABLE III. THE TRAINING ACCURACY OF ADL 5 CROSS-VALIDATION 1000HZ DATA

SUBJECT	RF (%)		CNN (%)		ADL (%)	
	Mean	STD	Mean	STD	Mean	STD
A	100,00	0,00	99,77	0,27	77,61	0,08
B	100,00	0,00	99,70	0,26	74,73	0,21
C	100,00	0,00	99,73	0,26	77,57	0,06
F	100,00	0,00	99,91	0,06	77,19	0,20
AVERAGE	100,00	0,00	99,78	0,21	76,77	0,14

TABLE IV. THE TESTING ACCURACY OF ADL 5 CROSS-VALIDATION 1000HZ DATA

SUBJECT	RF (%)		CNN (%)		ADL (%)	
	Mean	STD	Mean	STD	Mean	STD
A	48,29	1,18	68,56	1,09	77,75	0,33
B	52,03	0,34	71,53	0,82	74,61	1,02
C	55,51	0,78	69,50	1,24	77,49	0,27
F	59,08	0,74	79,26	0,79	77,20	0,77
AVERAGE	53,73	0,76	72,21	0,99	76,76	0,60

B. Subject-independent classification

In many cases, most EEG pattern recognition systems work well on the same subjects. However, the performance will be poor when it is trained with one subject and tested with different subjects. This section will test the performance of ADL for subject-independent classification. In this experiment, the system was trained using one subject and then tested using the rest of subjects. The experimental results are depicted in Figure 6 and Figure 7.

These two figures show that the ADL works very well on the subject-independent classification. The performance of ADL is similar to the subject-dependent classification. The average accuracy is around 78% over different four scenarios. It shows that the ADL is very promising for overcoming subject-independent classification that is most haunting the bio-signal pattern recognition implementation.

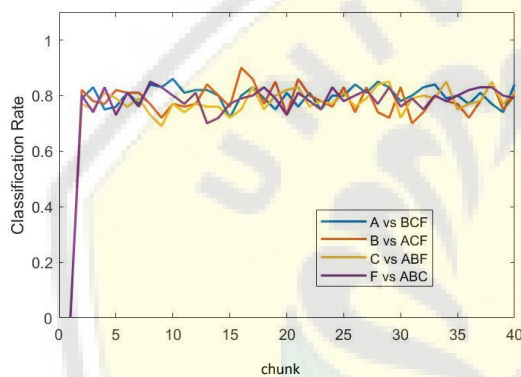


Figure 6 The testing accuracy of ADL on subject-independent classification on 5-fold cross-validation using data with a frequency of 200 Hz

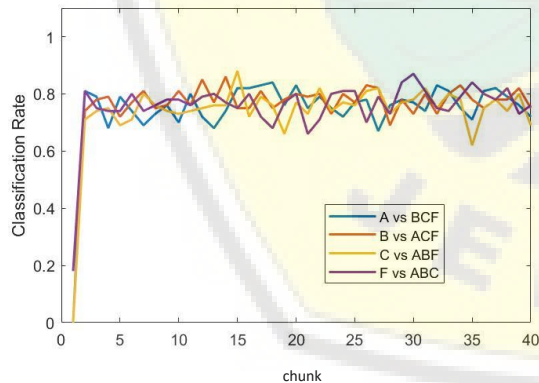


Figure 7 The testing accuracy of ADL on subject-independent classification on 5-fold cross-validation using data with a frequency of 1000 Hz

The benefit of ADL is more highlighted when it is compared to CNN, as shown in Table 5 and Table 6. Same as subject-dependent classification, the training accuracy of CNN is very good, almost 100%. Unfortunately, its testing accuracy is extremely bad. It became around 20%. On the contrary, ADL presents a promising performance. The accuracy did not decrease and tend to stable. The experimental results show that ADL is a promising solution for robustness issues in the bio-signal pattern recognition especially on EEG based system.

TABLE V. THE CLASSIFICATION ACCURACY OF CNN AND ADL USING 5 CROSS-VALIDATIONS ON 200 HZ DATA FOR SUBJECT-INDEPENDENT TEST

Scenario	TRAINING		TESTING	
	CNN	ADL	CNN	ADL
A vs BCF	99,95	79,15	22,10	77,46
B vs ACF	99,93	79,10	20,85	77,82
C vs ABF	99,89	77,83	21,07	81,62
F vs ABC	99,93	78,96	19,37	78,13
AVERAGE	99,93 ± 0,03	78,76 ± 0,63	20 ± 1,13	78,76 ± 1,93

TABLE VI. THE CLASSIFICATION ACCURACY OF CNN AND ADL USING 5 CROSS-VALIDATIONS ON 1000 HZ DATA FOR SUBJECT-INDEPENDENT TEST

Scenario	TRAINING		TESTING	
	CNN	ADL	CNN	ADL
A vs BCF	99,96	76,43	20,26	77,75
B vs ACF	99,59	77,46	20,02	77,82
C vs ABF	99,85	76,51	20,50	81,62
F vs ABC	99,95	76,55	20,96	78,13
AVERAGE	99,84 ± 0,17	76,74 ± 0,48	20,43 ± 0,40	78,83 ± 1,87

V. CONCLUSION

This article proposes a new method to overcome the degradation performance on the subject-independent classification by introducing a new brain-computer interface (BCI) based on autonomous deep learning (ADL). One of the main advantages of ADL is the ability to construct its structure itself and adapt to the changes in the input behaviors. The proposed BCI consists of CSP features and ADL. The goal is to classify five individual fingers based EEG signals. The experimental results on the subject-dependent classification show that the ADL outperforms random forest and CNN by producing stable accuracies on both training and testing about 78%. In the subject-independent classification, the virtue of ADL is more standing out compared to CNN. The ADL did not experience performance degradation, while CNN experienced a degradation performance of about 50%.

REFERENCES

- [1] D. Bright, A. Nair, and D. Salvekar, "EEG-Based Brain Controlled Prosthetic Arm," pp. 479–483, 2016.
- [2] Irwanto, E. R. Kasim, A. Fransiska, M. Lusli, and O. Siradj, "Analisis Situasi Penyandang Disabilitas di Indonesia: Sebuah Desk-Review," no. November, p. 32, 2010.
- [3] A. Ashfahani and M. Pratama, "Autonomous deep learning: Continual learning approach for dynamic environments," SIAM Int. Conf. Data Mining, SDM 2019, no. August, pp. 666–674, 2019.
- [4] Y. R. Tabar and U. Halici, "A novel deep learning approach for classification of EEG motor imagery signals," J. Neural Eng., vol. 14, no. 1, p. 16003, 2017.
- [5] M. Pratama, M. De Carvalho, E. Lughofer, and J. Lu, "ATL : Autonomous Knowledge Transfer from Many Streaming Processes ATL : Autonomous Knowledge Transfer from Many Streaming Processes," no. August, 2019.
- [6] S. Fazli, C. Grozea, M. Danóczy, F. Popescu, B. Blankertz, and K. R. Müller, "Subject independent EEG-based BCI decoding," Adv. Neural Inf. Process. Syst. 22 - Proc. 2009 Conf., pp. 513–521, 2009.
- [7] A. M. Ray et al., "A subject-independent pattern-based brain-computer interface," Front. Behav. Neurosci., vol. 9, no. OCTOBER, pp. 1–15, 2015.
- [8] M. Kaya, M. K. Binli, E. Ozbay, H. Yanar, and Y. Mishchenko, "A large electroencephalographic motor imagery dataset for electroencephalographic brain computer interfaces," Sci. Data, vol. 5, no. 1, p. 180211, Dec. 2018.
- [9] H. Meisheri, N. Ramrao, and S. Mitra, "Multiclass Common Spatial Pattern for EEG based Brain Computer Interface with Adaptive Learning Classifier," pp. 1–8, 2018.