# A Comparative Study of Vehicle Platoon with Limited Output Information in Directed Topologies

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***Abstract*—This paper aims to study and compare the effect of limited-output information in various directed topology to the performance of vehicle platoon. Two distributed controllers based on limited-output information will be compared to cooperative state variable feedback control which designed based on full-state information. The comparison will be conducted for four common directed topologies in the vehicle platoon application. Simulation analysis is performed in three scenarios, namely under normal operations, when the leader moves with constant acceleration and when the platoon is subjected to constant communication delay. Performances comparison will be observed from inter-vehicular distance response in each follower and the results will be displayed with respect to the follower vehicle index in the platoon configuration. Finally, the behavior of each control scheme in various topologies will be summarized.**

***Keywords— cooperative observer, cooperative state variable feedback control, directed topology, vehicle platoon***

## I. INTRODUCTION

Cooperative control of intelligent vehicles operating as a vehicle platoon attracts many researchers due to the potential application in the future transportation. In the vehicle platoon, each car is equipped with automatic driving capability and a vehicle-to-vehicle (V2V) communication technology. Each vehicle exchanges the necessary information to the connected neighbors according to the topology that is used. The collective information is used to develop a distributed cooperative control to maintain the inter-vehicular distance according to the predetermined spacing reference. At the same time, the synchronization of follower's velocity and acceleration to the leader should be achieved. Vehicle platoon is very useful to increase road capacity and to reduce congestion which will give implication of reducing emissions, and fuel consumptions [1].

A vehicle platoon is composed of vehicular longitudinal dynamics, information flow topologies, formation geometry and distributed controllers [2]. A linearized third-order model is commonly used to represent the vehicular longitudinal dynamics as used in [3]. Information flow topology can either be directed or undirected. Four common directed topologies are predecessor-following (PF), predecessor-following-leader (PFL), two-predecessor-following (TPF), and two-predecessor-following-leader (TPFL) [4]. While, vehicle platoon with undirected topology can either be bidirectional (BD) or bidirectional-leader (BDL) [5]. Formation geometry refer to the spacing policy. It can either be constant spacing policy (CSP) as in [4] or constant time heading (CTH) as in [6]. Finally, a distributed controller is applied in each follower to achieve the vehicle platoon objective. The controller utilizes collective information obtained by the onboard sensors in each vehicle and relative information received from the connected neighbors. Many literatures assumed that the full-state information is always available as in [3,4,6], where in reality many vehicles have limited information to be exchanged due to limitation of the sensor. This problem is solved by proposing the cooperative observer design as in [7].

Information about the behavior of vehicle platoon which applied distributed controller designed based on limited output information under directed topologies is rarely found in the literatures. This information is useful as a part of considerations in order to choose the best topology for vehicle platoon application. Therefore, this paper makes a comparative study of three control schemes applied in vehicle platoon under four commons directed topologies, namely PF, PFL, TPF and TPFL. The contribution of this work is to provide useful simulation analysis that shows the behavior of the control scheme designed based on limited information in each topology.

## II. SYSTEM DESCRIPTION

Vehicle platoon is a series of vehicles consisting of one leader and $N$-followers. All followers synchronize their states to the leader state according to the specified spacing policy. A leader is typically an autonomous vehicle that generates a reference and sends it directly to one or multiple followers. A follower is defined as a vehicle that applied distributed controller by utilizing the collective information from the neighbors. The follower also has capability to exchange the information to the connected neighbors and receive information from the leader either directly or indirectly depending on the topology that is used.

In this paper, the dynamics of the leader and follower that involved in the platoon can be described as

$$\dot{x}_0(t) = Ax_0(t), \tag{1}$$

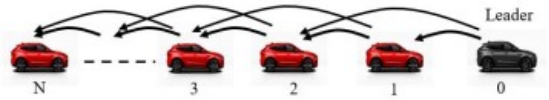
$$\dot{x}_i(t) = Ax_i(t) + Bu_i(t), i \in \{1,2,\dots,N\} \tag{2}$$

where $x_i(t) = [p_i + i \cdot d_r \quad v_i \quad a_i]^T$ for all $i \in \{0,1,2,\dots,N\}$, $u_i(t)$ is the control input for the follower $i$ and $\tau$ represents the inertial time lag of the powertrain system. The symbolizations $p_i$, $v_i$, and $a_i$ are used to express the position, velocity, and acceleration of the vehicle $i$, while $d_r$ is the constant desired distance. Here, $A$ and $B$ are

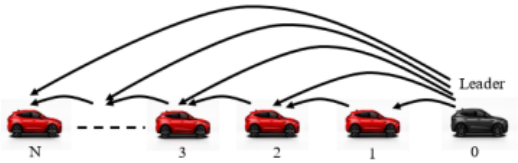
$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & -\frac{1}{\tau} \end{bmatrix} \text{ and } B = \begin{bmatrix} 0 \\ 0 \\ \frac{1}{\tau} \end{bmatrix}. \tag{3}$$

In order to represent the information exchange between followers, a digraph $\mathcal{G}(\mathcal{V}, \mathcal{E}, \mathcal{A})$ is used. Here, $\mathcal{V}$is a set of followers, $\mathcal{E}$ is a set of edges that represents the information exchange between followers and $\mathcal{A} = [a_{ij}] \in \mathbb{R}^{N \times N}$ is the

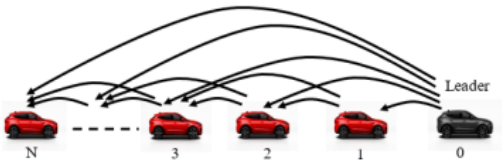

(a) PF




(b) TPF




(c) PFL




(d) TPFL

Fig. 1. Directed topologies of platoon vehicles.

adjacency matrix. The value of $a_{ij} = 1$ if and only if vehicle $i$ can receive information from vehicle $j$, otherwise $a_{ij} = 0$. The in-degree matrix is denoted by $D = diag\{d_{11}, d_{22}, \dots, d_{NN}\}$, where $d_{ii} = \sum_{j=1}^{N} a_{ij}$. The Laplacian matrix $\mathcal{L}$ is defined as $\mathcal{L} = D - \mathcal{A} \in \mathbb{R}^{N\times N}$ with diagonal elements $\ell_{ii} = d_{ii}$ and the other elements given by $\ell_{ij} = -a_{ij}$. A pinning matrix is defined as $G = diag\{g_{11}, g_{22}, \dots, g_{NN}\}$, where $g_{ii} = 1$ means that follower $i$ can receive information directly from the leader, otherwise $g_{ii} = 0$.

This paper will explore the behavior of most common directed topologies, namely PF, PFL, TPF, and TPFL as shown in Fig.1. All topologies in Fig. 1 are contains spanning tree with the leader (black vehicle) as a root node.

Since this paper employs constant spacing policy (CSP), therefore the objective of platoon vehicles is to maintain a constant inter-vehicular distance while synchronizing the velocity and acceleration of each follower to the leader. It can be formulated as

$$\begin{cases} \lim_{t\to\infty} \|p_i(t) - p_j(t)\| = (i-j)d_r \\ \lim_{t\to\infty} \|v_i(t) - v_0(t)\| = 0 \\ \lim_{t\to\infty} \|a_i(t) - a_0(t)\| = 0 \end{cases}. \quad (4)$$

## III. DISTRIBUTED CONTROLLER

In this paper, the behavior of three control schemes in [7] will be studied under various directed topologies. These control schemes are Cooperative State Variable Feedback Control (CSVFB), Neighborhood Controller Neighborhood Observer (NCNO) and Neighborhood Controller Local Observer (NCLO). CSVFB is used as an ideal comparation in order to see the effect of the limited output information in the performance of the platoon. These control schemes are summarized from [7] as follows:

### A. Cooperative State Variable Feedback Control

CSVFB is designed based on the assumption that full-state information is available. The controller is designed as,

$$u_i = cK \sum_{j=1}^{N} \{a_{ij}(x_j - x_i)\} + g_{ii}(x_0 - x_i) \quad (5)$$

where $c > 0$ is a coupling gain, $K \in \mathbb{R}^{m\times n}$ is the feedback gain matrix chosen as follows,

$$K = R^{-1}B^T P_1. \quad (6)$$

Matrix $P_1$ is a solution of the algebraic Riccati equation (ARE)

$$0 = A^T P_1 + P_1 A + Q - P_1 B R^{-1} B^T P_1, \quad (7)$$

where $Q$ and $R$ are positive definite.

### B. Neighborhood Controller Neighborhood Observer

Different from CSVFB, NCNO is designed based on limited output information. Denote $\hat{x}_i$ as the estimation of $x_i$, while $\hat{y}_i = C\hat{x}_i$ is the estimation of $y_i$. By defining $\tilde{x}_i = x_i - \hat{x}_i$ as the state estimation error and $\tilde{y}_i = y_i - \hat{y}_i$ as the output estimation error, the cooperative output estimation error can be formulated as

$$\mu_i = \sum_{j=1}^{N} a_{ij}(\tilde{y}_j - \tilde{y}_i) + g_{ii}(\tilde{y}_0 - \tilde{y}_i). \quad (8)$$

The cooperative observer for each follower is designed as

$$\dot{\hat{x}}_i = A\hat{x}_i + Bu_i - cF\mu_i, \quad (9)$$

where $F$ is the observer gain which can be defined as

$$F = P_2 C^T R^{-1}, \quad (10)$$

where $P_2$ is solution of the observer algebraic Riccati equation (ARE)

$$0 = A^T P_2 + P_2 A + Q - P_2 C^T R^{-1} C P_2. \quad (11)$$

Instead of using (5), $u_i$ in (9) is designed as

$$u_i = cK \sum_{j=1}^{N} \{a_{ij}(\hat{x}_j - \hat{x})\} + g_{ii}(\hat{x}_0 - \hat{x}_i). \quad (12)$$

The closed loop dynamics of follower $i$ can be obtained by substituting (12) into (2).

### C. Neighborhood Controller Local Observer

This control scheme is a modification of NCNO, where instead of using the complete neighborhood output estimation error, this controller only uses the local output estimation error. Therefore, the cooperative observer can be defined as

$$\dot{\hat{x}}_i = A\hat{x}_i + Bu_i - cF\tilde{y}_i, \quad (13)$$

while, $u_i$ in (13) uses the same design as (12). Again, the closed loop dynamics of follower $i$ can be obtained by substituting (12) into (2).

## IV. SIMULATION AND ANALYSIS

For simulations, a vehicle platoon consisted of 1 leader and 5 followers with the desired distance $d_r = 5$ m is selected. All vehicles are homogeneous with the inertial time lag $\tau = 0.25$. Four directed topologies as shown in Fig. 1 are used in this study. For NCNO and NCLO, it is assumed that only information about position of each vehicle can be obtained, therefore $C = [1 \quad 0 \quad 0]$. In order to design the controller, $Q = I_{3\times3}$ and $R = 0.01$ are selected which resulting

$$K = [10.0000 \quad 17.5946 \quad 9.4784], \tag{14}$$

$$F = [175.9456 \quad 104.7842 \quad 2.5000]^T. \tag{15}$$

It should be noted that tuning $Q$ and $R$ is trade-off between consensus tracking performance and a realistic control input. The higher the $Q$ value, the better the transient response and consensus tracking, but at the cost of increasing the initial control signal. While the value of $R$ has the opposite effect of $Q$.

The simulation will be conducted in three scenarios, namely (i) under normal operations, (ii) when the leader moves with constant acceleration, and (iii) when all vehicles subjected to constant communication delay. Performance comparisons are observed based on the inter-vehicular distance in each follower.

### A. Normal Operations

Normal operations mean that each scheme is simulated based on the ideal control design assumptions, namely based on ideal communication and leader moves with constant velocity. In order to verify the performances, overshoot and settling time in each follower are selected to be observed. The profiles of the overshoot in each follower is shown in Fig. 2 while for the settling time is shown in Fig. 3. The analysis in overshoot responses can be summarized as follows:

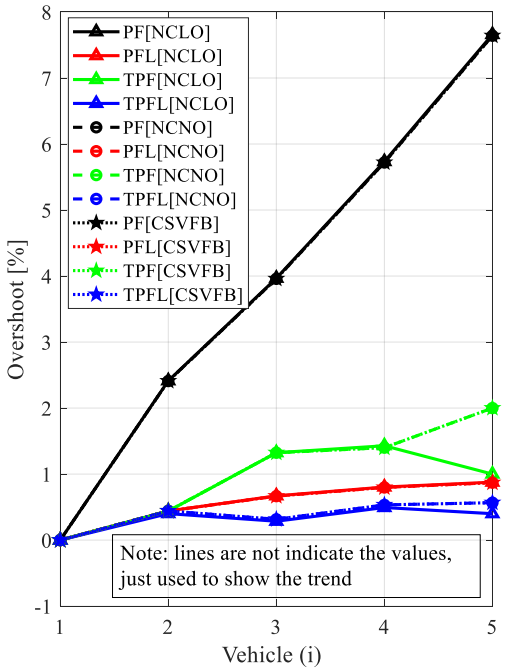



Fig. 2. The percent overshoot of the inter-vehicular distance error under normal operations

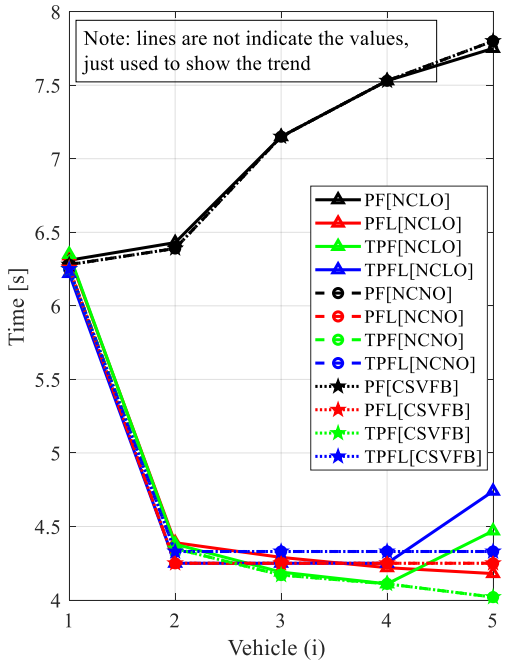



Fig. 3. The settling time of the inter-vehicular distance error under normal operations

- PF and PFL have similar characteristics, namely the bigger the index of the vehicle the bigger the overshoot. However, PFL has significantly smaller slope compared to PF.
- Platoon with complex topology has better overshoot along the tail end of the platoon. It shown that TPFL has the best result.
- Interestingly, limited output information does not give significant effect in the overshoot of platoon in various directed topologies, compared to full-state information.

While, the analysis in settling time can be summarized as follow:

- Settling time of each platoon's member with PF topology are shown increase along the tail end of the platoon, while platoon with PFL, TPF and TPFL are shown decrease significantly. It shown that TPF has the best performance when full-state information is available. However, when limited output information is used, PFL shows the best.

### B. Leader Moves with Constant Acceleration

Moving with acceleration is unavoidable in real driving. These control schemes have drawback when the leader has nonzero input which will result a steady-state distance error in each follower. Therefore, this subsection analyzed the behavior of each topology when the leader has constant input (moves with constant acceleration). The comparison result is shown in Fig. 4. The analysis of the steady-state distance error in each follower can be summarized as follows:

- Constant input leader affects all the PF platoon's members which resulting uniformly constant steady state distance error.

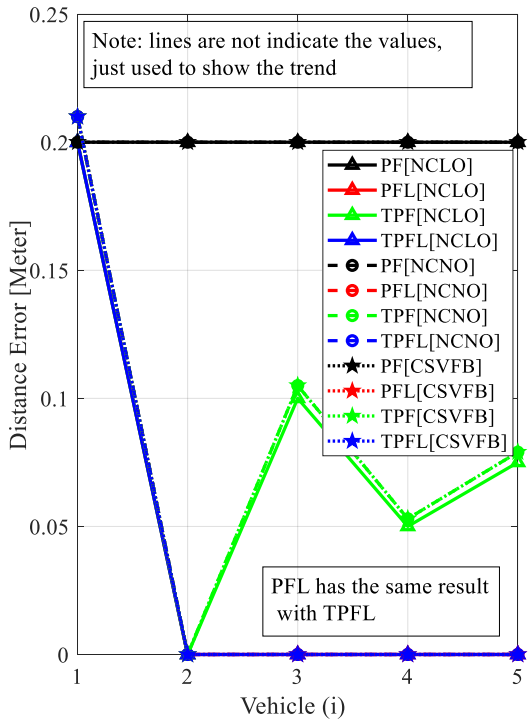



Fig. 4. The inter-vehicular distance error when the leader has constant input

- Interestingly, platoon with PFL and TPFL the effect only occurred the first follower, while the remaining followers have zero steady state distance error.
- TPF shows that the steady state distance error is oscillating with respect to the vehicle index.
- Again, the effect of full-state and limited output information are shown insignificantly.

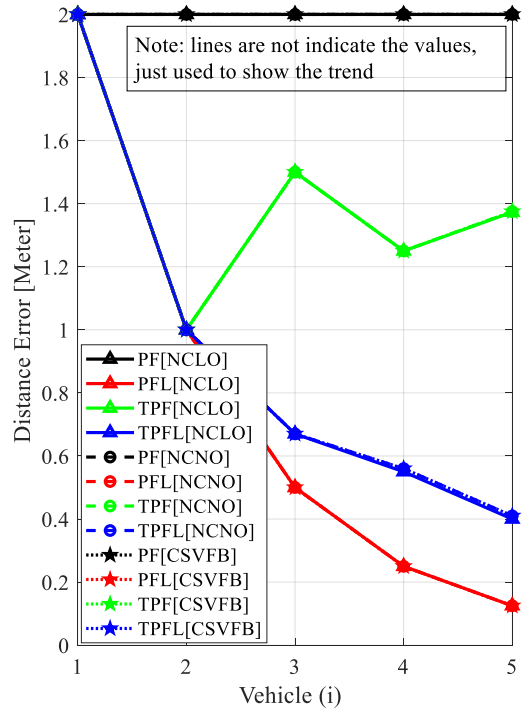



Fig. 5. Inter-vehicular distance with constant communication delay

### C. *Platoon Subjected Constant Communication Delay*

It is assumed that all vehicles subjected to uniformly constant communication delay with $t_d = 0.1$ s. The performance comparison is shown in Fig. 5. The analysis can be summarized as follows:

- PF has uniformly steady state distance error along the platoon members.
- PFL and TPFL shown that the distance error is significantly decreased along the tail end of the platoon.
- PFL shows the best results among the directed topologies.
- Full-state and limited state information give similar performances when the platoon subjected to constant communication error

## V. CONCLUSION

A comparative study of vehicle platoon with limited output information in four common directed topologies was conducted. In normal condition, it is shown that vehicle platoon with the most complex topology, TPFL, has the best overshoot's profile along the tail end of the platoon. However, in term of settling time, PFL is the best. Again, PFL and TPFL outperforms the others when the leader moves with constant acceleration. Similar results are shown when the platoon is subjected to constant communication delay. Finally, compared to full-state information, the performances of vehicle platoon with limited output information are shown similar when the platoon is subjected to constant communication delay and when the leader moves with constant acceleration. In normal condition, limited output information did not give significant effect in the overshoot and settling time.

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## Metadata

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## Contents



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| Time | Room 1 | Room 2 | Room 3 |
|---|---|---|---|
| **Wednesday, January 18** | | | |
| 13:00-14:00 | WedA1: Workshop on AI in Robotics by Ascendas | | |
| 14:15-17:00 | WedA2: Workshop on Brain Power Development Toward ASEAN Factori 4.0 | | |
| **Thursday, January 19** | | | |
| 08:45-09:15 | Keynote Speaker I - Prof. Shyh-Leh Chen | | |
| 09:15-09:45 | Keynote Speaker II - Prof. Radom Pongvuthithum | | |
| 10:00-11:30 | ThuA1: ECTI-ICROS Special Session on Advanced Control Designs and Applications | ThuB1: Artificial Intelligence I | ThuC1: Instrumentation and Smart Agriculture |
| 13:00-14:30 | ThuA2: ECTI-SICE Special Session on Advances in Control Engineering and Applications | ThuB2: Artificial Intelligence II | ThuC2: Control Theory , Automation and Control Applications |
| 14:45-16:00 | ThuA3: Robotics | ThuB3: Special Session on Data Science and Artificial Intelligence for Disaster Risk Reduction | ThuC3: Power Control and Energy Systems |

# Wednesday, January 18

## Wednesday, January 18 13:00 - 14:00

### WedA1: Workshop on AI in Robotics by Ascendas

Empower Your Robots with AI using MATLAB

Ms. Kantika Wongkasem

Chairs: Thongchart Kerdphol (Kasetsart University, Thailand), Peerayot Sanposh (Kasetsart University, Thailand)

**Abstract:** AI-powered robots continue to expand in use for manufacturing facilities, power plants, warehouses, and other industrial sites. Warehouse bin-picking is a good example. In an e-commerce fulfillment warehouse, human workers need to pick and place millions of different products into boxes based on customer requirements. Deep learning and reinforcement learning now enables robots to learn to handle various objects with minimum help from humans. In this talk, you will learn how to empower your robots using deep learning and reinforcement learning for perception and motion control in autonomous robotics applications including robot manipulators, autonomous mobile robots, and UAVs using MATLAB.

**Biography:** Ms. Kantika Wongkasem specializes in the areas of Image processing and Convolution neural network are a subset of machine learning, and they are at the heart of deep learning algorithms. Kantika received her a bachelor's degree from King Mongkut's Institute of Technology Ladkrabang with senior project Sign Language Detection use webcam camera to study image processing and learning algorithms with MATLAB. and now studying Master degree in Engineering Technology at Thai-Nichi Institute of Technology with research image processing analysis application.

## Wednesday, January 18 14:15 - 17:00

### WedA2: Workshop on Brain Power Development Toward ASEAN Factori 4.0

Chairs: David Banjerdpongchai (Chulalongkorn University, Thailand), Roungsan Chaisricharoen (Mae Fah Luang University & School of Information Technology, Thailand)

**WedA2.1 14:15** ***Training of Trainers for South-East Asia in the Industry 4.0 Context: Implementation of Platforms***

Jean-Marc Thiriet (Université Grenoble Alpes, France); Denis Genon-Catalot (University Grenoble Alpes - Grenoble INP & LCIS, France); Kanthanet Tharot (Univ. Grenoble Alpes, France); Stephane Mocanu (Grenoble Institute of Technology, France); Emil Novakov (IMEP, France); Kosorl Thourn (Institute of Technology of Cambodia, Cambodia); Roungsan Chaisricharoen (Mae Fah Luang University & School of Information Technology, Thailand); Hamed Yahoui (Université de Lyon, France); Denis Lubineau (Univ. Grenoble Alpes, France); Phosy Panthongsy (National University of Laos, Laos)

Asean-Factori 4.0 is a Key Action 2 of the European Union. This project, managed by Université Claude Bernard Lyon 1, regroups three European partners: Lyon (FR), Ruse (BG) and Grenoble (FR) together with 7 partners in South-East Asia (Asean) in Cambodia, Laos and Thailand. The main concept of the project is to train Asian teachers, around innovative platforms proposed by the European colleagues. The Asian institutions should create together a network of excellence; to this aim, each Asian institution will receive a specific platform with a specific focus and from a specific brand. The paper describes the state of

advancement and the work achieved by the Grenoble partner (UGA, Univ. Grenoble Alpes) together with the Asian partners: ITC (Institut de Technologie du Cambodge, KH), NUOL (National University of Laos, LA) and MFU (Mae Fah Luang University, TH). A first training was organized in Grenoble in the spring 2022. ITC and MFU attended on-site whereas NUOL attended on-line. A second training is organized on-site at the Asian partner institution, after the transfer of the platform in Asia; the purpose is for the partners to take their platform in hand.

### WedA2.2 14:30 *Education Technology: Integrate Database into Computer Courses for University of Health Sciences Students*

Lattanavong Thammabanvong (University of Health Sciences & Asean Factori Project, Laos)

This article is dedicated to the integration of database management ‘MySQL lesson' into computer course for the University of Health Sciences students. The article deals with the problem of ICT tool for the healthcare professional. The survey has been made to acknowledge the understanding and knowledge of lecturer, student, and medical staff. The introduction of database management will improve students' awareness and understanding of the future profession.

Index Terms - Database, MySQL, ICT, Medical Sciences, HIS.

### WedA2.3 14:45 *Readiness Assessment of Seminar-Holding in Industry 4.0 Context: PLC Training in National University of Laos*

Phosy Panthongsy, Vimontha Khieovongphanchanh, Phutsavanh Thongphanh and Phanxay Chanthavong (National University of Laos, Laos); Denis Genon-Catalot (University Grenoble Alpes - Grenoble INP & LCIS, France); Jean-Marc Thiriet (Université Grenoble Alpes, France); Hamed Yahoui (Université de Lyon, France)

In the fourth industrial revolution (Industry 4.0), Programable Logic Controller (PLC) is one of the promising technologies that enables the smart and autonomous systems. It is a reason that the education sector has made a continual effort to update the lessons around PLC in the curriculum. The National University of Laos (NUOL) also has implemented the same way, which is supported by the European Commission under the framework of the ERASMUS+; through ASEAN-Factori 4.0 project. One of the project activities is to provide the seminar in a classroom with many students. To ensure the readiness of seminar-holding, the aim of this paper is to validate the teaching plan with a real simulation by training 6 students on PLC. The learning outcome, duration of session, teaching methodology, learning task and resources are evaluated. As a result, the teaching plan seems to be good. The contents and duration of session needs to be optimized due to the ability and profile of students.

### WedA2.4 15:00 *Becoming CU Asean Factori 4.0 Training Center for Programmable Logic Controller*

Sirikanya Singcuna (Chulalongkorn University & Engineering, Thailand); Paisan Kittisupakorn and David Banjerdpongchai (Chulalongkorn University, Thailand); Plamen Daskalov and Tsvetelina Georgieva (University of Ruse Angel Kanchev, Thailand); Plamen Z. Zahariev (University of Ruse, Bulgaria); Nina Bencheva (University of Ruse Angel Kanchev, Thailand); Hamed Yahoui (Université de Lyon, France); Jarukamol Dawkrajai (Chulalongkorn University, Thailand)

Industry 4.0 concept is a worldwide movement to increase production efficiency. Thailand 4.0 deploying Industry 4.0 concept is a 20-year strategy acceded by the Royal Thai Government to uplift the income status. The European Erasmus+ programme granted the partners from Europe and South-East Asia countries through the ASEAN FACTORI 4.0 project incorporated Industry 4.0 to prepare the future qualified technical human resources for advanced manufacturing and processing machinery. Chulalongkorn university (CU) was one of six ASEAN partners, together become the Training Centers forming a network of excellence and allowing exchanges of competences and experiences between partners. The intensive training course was held at University of Ruse (UR) "Angel Kanchev" to prepare the academic staffs on the programmable logic controller (PLC) as well as coding with CODESYS and Galileo software to control devices of the benchmark for the CU's Center of Excellence. After the training at UR, the training course was conducted at CU to students from Electrical Engineering Department and Chemical Engineering Department. The training shall be integrated to the revised curricula of three courses, namely, Industrial Automation under Electrical Engineering Program, Process Dynamics and Control, and Instrumentation in Chemical Process under Chemical Engineering Program.

**WedA2.5 15:15** ***Curricula Improvement of Undergraduate Program in Electrical Engineering Department at ITC Under ASEAN Factori 4.0 Project***

Kosorl Thourn, Bunthern Kim, Vannak Vai and AM Sok Chea (Institute of Technology of Cambodia, Cambodia); Jean-Marc Thiriet (Université Grenoble Alpes, France); Hamed Yahoui (Université de Lyon, France); Koksal Chou and Samphors Eng (Institute of Technology of Cambodia, Cambodia)

The ERASMUS+ project, ASEAN Factori 4.0, is a collaboration between partner universities in Europe and South-East Asia to improve the curricula of Asian partner universities in Thailand, Laos, and Cambodia. Several activities such as surveys, seminars, training, etc., have been carried out and are on the way within the project to test the proposed solution and provide best practices for curricula modification. This paper describes the process of updating the existing courses around Industry 4.0 context in the field of control and automation in the department of Electrical and Energy Engineering at the Institute of Technology of Cambodia.

**WedA2.6 15:30** ***Curriculum for Embedding Industry 4.0 to a Computer Engineering Program***

Roungsan Chaisricharoen (Mae Fah Luang University & School of Information Technology, Thailand); Punnarumol Temdee, Chayapol Kamyod and Santichai Wicha (Mae Fah Luang University, Thailand); Jean-Marc Thiriet (Université Grenoble Alpes, France); Hamed Yahoui (Université de Lyon, France)

The presence of Industry 4.0 has changed the requirements of industrial workforces. Previously, the staff responsible for information systems and plant operation were divided and worked differently in concepts and methods. However, the convergence of Industry 4.0 has encouraged the industry to have maintenance workforces capable of both information processing and machine maintenance. In response, a new computer engineering curriculum previously aimed at the computing industry desired to embed a particular set of PLC contents into its existing curriculum to expand the possible working area for its graduates. The process is supported by the Asean Factori 4.0, an ERASMUS+ Project funded by the European Union. Through the effort, a new branch of elective courses and a few required courses are synthesized to add the PLC's skills that can be integrated into other branches.

**WedA2.7 15:45** ***Accreditation Process of Modification Course: A Case of PLC Program Course, Department of Electrical Engineering, Faculty of Engineering, SKU***

Sitha Khemmarath, Khonesavanh Norasane and Phoumdavone Sombounsack (Savannakhet University, Laos)

Since resent years ago Electrical Engineering is the most popular mayor in Lao PDR. As higher education in Lao is evolving rapidly and to ensure high education quality standards, all of institutions of higher education need to be accredited by the ministry of Education and sport of Lao (MoEs). Most of faculty members do not like the accreditation process as they have the misconception that it is an exhausting time consuming, not to say complex and unnecessary, process. Most faculty members are not enthusiastic about going through the preparation process and its requirements from data collection, documents and forms preparation, data aggregation, data analysis, collecting evidences, and developing corrective action and future plans as needed. This paper describes requirements for programs accreditation, the preparation process, and the challenges faced during the accreditation process. There are some documents discussing about issue related to accreditation process in University of Laos. They show the important of the accreditation process. Otherwise, authors believe that the challenges association with the accreditation process and their cause are not fully reported and very important to presented. The university needs to realize those challenges to try to avoid them and make the accreditation process easier and smoother. Knowledge and information gained via observation, interviews with faculty members, discussions with colleagues from different universities of Laos, and extensive involvement of the authors in the accreditation process of opening new course is utilized to state challenges and barriers experienced throughout different stages of the accreditation journey. Currently, there is one institutional accreditation bodies in Laos; ministry of education and sports. This study concludes the fact of accreditation process; challenges and benefits of accreditation to the programs and institution is the key success factor in attaining accreditation.

Terms: Accreditation, Curriculum Accreditation, Accredit process, PLC and ASEAN Factori 4.0.

# Thursday, January 19 8:45 - 9:15

## Keynote Speaker I - Prof. Shyh-Leh Chen

Contouring Control of Multi-axis Motion Systems with Equivalent Contour Errors

Prof. Shyh-Leh Chen

**Abstract:**Contouring control is an important motion control task for multi-axis motion systems. It requires that the output position of the system follow a given path in the task space. The contouring control problem can be found widely in the applications of robotics, computer-numerical-controlled (CNC) machine tools, etc. It aims at reducing the contour error, which is defined by the minimum distance between the actual output position of the system and the desired path. Improving the contouring accuracy is an important problem since it directly affects the product quality. One major difficulty in this problem is the representation of the contour error in terms of the measurable axis displacements. In general, such representation requires complicated nonlinear functions and analytical form may not be available. Most approaches adopt linear approximation and hence the performance of the contouring controller may be degraded.

In this talk, the concept of equivalent contour error will be introduced. The equivalent contour error is based on the algebraic equations that describe the desired path. It is equivalent to the actual contour error in the sense that reducing it is equivalent to reducing the actual contour error. Thus, the equivalent contour error can be taken as an alternative control objective. No approximations are needed and excellent contouring performance can be achieved. We have developed the method for systems without constraint, with holonomic or non-holonomic constraints. The method has been successfully applied to a variety of practical systems, including multi-axis machine tools, robot manipulators, Stewart platform, and two-wheeled inverted pendulum system.

**Biography:** Shyh-Leh Chen received B.S and M.S. degrees from National Tsing-Hua University, Hsin-Chu, Taiwan, in 1987 and 1989, respectively, both in power mechanical engineering. He received a Ph.D. degree in mechanical engineering from Michigan State University, East Lansing, Michigan, USA, in 1996. Since 1996, he has been with National Chung Cheng University, Chiayi, Taiwan, where he is currently a Distinguished Professor in the Department of Mechanical Engineering. His research interests include nonlinear dynamics and control, wavelet analysis, with application to motion control of multi-axis systems, active magnetic bearings, and ship stabilization.

Prof. Chen has organized and chaired 7 international conferences. He received the Automatic Control Award for Young Scholars and Outstanding Automatic Control Award from Chinese Automatic Control Society in 2003 and 2015, respectively, Outstanding Teaching Award from CCU in 2006, Delta Award from IEEE Tainan section in 2017, and Distinguished Research Award from CCU in 2018. He is a Fellow of Chinese Automatic Control Society. He is an associated editor for Mechatronics (since 2021) and IEEE Transactions on Automation Science and Engineering (since 2022).

# Thursday, January 19 9:15 - 9:45

## Keynote Speaker II - Prof. Radom Pongvuthithum

Control Designs for Time-Delay Nonlinear Systems with Lower-Triangular Structures and Unknown Control Directions

Prof. Radom Pongvuthithum

**Abstract:** A class of nonlinear systems in the lower triangular form has attracted considerable attention from researchers because many physical systems, including mechanical, electrical and bio-chemical systems, can be transformed into a lower-triangular form. System uncertainties naturally arise due to lack of knowledge of the system, or system conditions changing from internal or external factors. These uncertainties can include structural uncertainties, parametric uncertainties, time-delays and control directions. The less system information is used in the control design, the more robust the controller becomes.

This presentation discusses various control designs for nonlinear systems in the lower-triangular form and beyond that can deal with structural uncertainties, parametric uncertainties and recent developments in control designs for unknown time-delays in states and unknown control directions.

**Biography:** Dr. Radom Pongvuthithum received his Ph.D. from the Department of Electrical Engineering and Computer Science, Case Western Reserve University, Ohio, in 2003. From 2003-2004, he was a Research Fellow in the School of Engineering and Sciences at the University of Southampton, U.K. He joined the Department of Mechanical Engineering, Chiang Mai University, Thailand, in 2004 and currently holds the position of Professor in the same department. His research interests include nonlinear systems, adaptive control, time-varying feedback design and their applications to medical robots and energy systems.

# Thursday, January 19 10:00 - 11:30

## ThuA1: ECTI-ICROS Special Session on Advanced Control Designs and Applications

Chairs: PooGyeon Park (POSTECH, Korea (South)), Napasool Wongvanich (KMITL, Thailand)

**ThuA1.1 10:00** ***An LMI Approach to State Feedback Control of Non-Polynomial Systems with Input Constraints***

Phing Lim and David Banjerdpongchai (Chulalongkorn University, Thailand)

This paper aims to design a state feedback controller for non-polynomial systems with bounded control inputs. The problem formulation begins by transforming the non-polynomial systems into polynomial systems. This can be done by defining non-polynomial terms as new state variables with algebraic constraints satisfying the non-polynomial properties. This method avoids the approximation of the recast polynomial systems. Then we design the state feedback control based on the extended Lyapunov stability theorem with the quadratic performance criterion. The design conditions are derived in terms of linear matrix inequality constraints. An upper bound of the optimal quadratic cost function can be readily obtained using available LMI solvers. The numerical results for the inverted pendulum on cart demonstrate the effectiveness of the proposed control design.

**ThuA1.2 10:15** ***Stability and Hopf Bifurcation Analysis of Delayed Food-Chain Model with Fear and Harvesting***

Sivasamy Ramasamy and David Banjerdpongchai (Chulalongkorn University, Thailand)

We consider the influence of fear and species harvesting in a delayed three-species food-chain model, where interference among the species is determined by Holling type-II functional response. The proposed model incorporates the growth rate of prey. Middle-predators are decreased because of the fear of middle and special-predators. The species are harvested through a constant effort strategy. Time delay is imposed to utilize the impact that prey takes some time to convert the food into its growth. The essential conditions for the existence of ecologically possible equilibrium points and their local stability are derived. In addition, we derive the conditions for the occurrence of Hopf bifurcation for delayed and non-delayed models. The derived results are examined through numerical examples.

**ThuA1.3 10:30** ***Consensus Condition Based on Free-Matrix-Based Integral Inequality for Multi-Agent Systems with Time Delays***

HoSub Lee and PooGyeon Park (POSTECH, Korea (South))

This paper proposes the consensus condition based on free-matrix-based integral inequality for multi-agent systems with time-varying delays. The use of free-matrix-based integral inequality derives increasing the freedom between the states and their derivatives. The simulation results of a numerical example show that the proposed criteria are less conservative than the existing criteria, and achieve a consensus of multi-agent systems.

**ThuA1.4 10:45** ***Combined Step-Size Generalized Continuous Mixed p-Norm Algorithm***

Minho Lee, Seung Hyun Ryu, Chan Park and PooGyeon Park (POSTECH, Korea (South))

This paper proposes a robust combined step-size generalized variable step-size continuous mixed p-norm (CSS-GVSS-CMPN) algorithm to improve performance in an environment with impulsive noise. GVSS-CMPN algorithm is derived from a CMPN cost function and has outstanding performance. The proposed algorithm introduces a combined step-size (CSS) strategy to resolve the trade-off problem that occurs in the GVSS-CMPN algorithm. A variable mixing factor designed by using a sigmoidal activation function is applied to obtain a fast convergence rate and low steady-state error. A variable mixing factor is indirectly updated by using an inner parameter, and the update equation of the variable mixing factor is derived by optimizing an (\ell_1) norm of \textit{a priori} error. The sigmoidal activation function is modified and applied to the variable mixing factor for practical considerations. Simulation results show that the proposed algorithm has the best performance among compared algorithms in the environment with impulsive noise.

**ThuA1.5 11:00** ***Denoising and Demodulation in CW Radar: A Machine Learning Approach Based on Synthetic Vital Signals***

Won Yeol Yoon (Yeungnam University & Intelligent Control and Automation System Lab., Korea (South)); Byeong Jun Kim and Nam Kyu Kwon (Yeungnam University, Korea (South))

This paper proposes a machine learning approach based on synthetic data for denoising and demodulation in continuous-wave (CW) radar. In particular, vital signals detected from CW radar have a characteristic that it is difficult to obtain sufficient data for machine learning. To remedy the above problem, we design a data collector that can create the synthetic CW radar signals. First, we create data representing the displacement from the subject, which has heart rate and respiration information. Then, two synthetic signals are also generated based on the displacement and physical property. To take into account noise that may occur in real-world measurement situations, baseline noise and baseline drift such as sigmoid, hyperbolic tangent and sinusoidal function are added to the synthetic signals. The synthetic signals are applied to the neural network, which is replacing the denoising and demodulation process. In addition, neural networks are divided into two types according to the time of signal concatenation. Finally, we analyze the feasibility of this method and compare the performance of the model through Signal-to-Noise Ratio(SNR) and Root Mean Square Error(RMSE).

**ThuA1.6 11:15** ***Deep Reinforcement Learning with HER for Path Planning of Mobile Robot***

Min Jae Park, Byeong Jun Kim and Nam Kyu Kwon (Yeungnam University, Korea (South))

In this paper, we propose a method to overcome the sparse reward problem that can occur in autonomous driving of mobile robot based on deep deterministic policy gradient learning using simple reward engineering and the HER technique. The mobile robot used in the experiment is ROS-based Turtlebot3, and the experimental environment is configured using Gazebo. To demonstrate the effectiveness of the proposed technique, we present the experimental results on the application of HER.

# ThuB1: Artificial Intelligence I

Chairs: Koonlachat Meesublak (NECTEC, Thailand), Rardchawadee Silapunt (King Mongkut's University of Technology Thonburi, Thailand)

**ThuB1.1 10:00** ***Monocular Visual Odometry for Small UAVs***

Sutthiphong Srigrarom (National University of Singapore & Temasek Laboratories, Singapore)

This paper explores the practical implementation of an algorithm for Monocular Visual Odometry for Small Unmanned Aerial Vehicles (UAVs). The type of UAV in question are those that are commercially available to the mass market such as those manufactured by DJI. This paper found that the developed algorithm, which requires a constant altitude and gimbal pitch, is a good tool for the estimation of the drone's position and velocity. The current algorithm can be used in scenarios where absolute positional accuracy is not critical.

**ThuB1.2 10:15** ***Point Cloud Based Guidance for Autonomous Mobile Robot in Sugarcane Plantation***

Surachai Rodsai and Chowarit Mitsantisuk (Kasetsart University, Thailand); Atsushi Takahashi (Tokyo Institute of Technology, Japan); Anusorn Iamrurksiri (National Metal and Materials Technology Center, Thailand)

In this study, we propose a way to autonomously navigate an agricultural mobile robot in a sugarcane plantation. Typically, before planting, regularly spaced rows of raised seed beds are formed, resulting in U-shaped furrows. Thus, we utilize these U-shaped furrows as a mean to automatically navigate the mobile robot. To achieve this goal, the RGB-Depth camera is used to create 3D cloud point data of the furrows. We develop a method for determining the slopes of the bed form using the cloud point data to identify the exact position of the furrows so that the mobile robot can autonomously navigate through the entire row of each furrow without stepping into the bed form.

**ThuB1.3 10:30** ***A Method for Football Players Detection on the Soccer Field by Integrated Image Processing Techniques***

Pachara Tumtong and Phokin Promvijittrakarn (Srinakharinwirot University, Thailand); Paanchat Pattanaworapan (Laboratory School Centre for Educational Research And Development, Thailand); Theekapun Charoenpong (Srinakharinwirot University, Thailand)

the player detection algorithm in a soccer field image is an important step for an offside situation detection. A difficulty of player detection occur when the player is overlap with the crowd of cheering. In this paper, we propose a new method for football player detection on the soccer field by integrated image processing techniques. This method consists of two steps. Firstly, the soccer field area is segmented from the background. This step is used to avoid the error of player detection from overlap problem between player and crowd of cheering. Finally, the process to detect players in the soccer field from Morphological. To test the performance of the proposed method, the images used to test in this research have 150 images from three football matches. The detected players compared with the total players on the field by visual. Detection rate is 85.943% and the accuracy of the player detection process is 76.63%. The result show that the proposed method is satisfactory in order to continue for performance improvement.

**ThuB1.4 10:45** ***Residential Versus Migratory Bird Flight: Classification by Trajectories Characterization***

Sutthiphong Srigrarom (National University of Singapore & Temasek Laboratories, Singapore); Chonnapatt Phichayophas and Suwarin Pattanachuanchom (Kasetsart University, Thailand)

This paper presents a proof of concept for classifying migratory birds from residential birds in Near-Field using an alternative method, by examining the nature of their flight paths, patterns, and trajectories. Multiple videos containing natural and artificial databases of flying birds were used to extract their flight trajectories. For them to fly over a long distance, migratory birds, Canadian Geese, for example, have much higher physical strength and lower body weight compared to residential birds. Therefore, due to their nature and physical limitations, migratory birds fly in folk, usually with considerably more predictable and periodic (due to their flapping motion) fight paths without drastic changes in their heading. Whereas residential birds, on the other hand, fly or sometimes glide in shorter distances and sections from point A to point B, so they can change their heading and acceleration very quickly or even in mid-air. Four (4) trajectories characteristics and observed from the bird's flight paths: turning angle, periodicity (frequency), and object pace (velocity and acceleration). Hereafter, principal component analyses were applied to reduce the number of these trajectory features from 4 to 2 parameters. Support vector machine (SVM) with Quadratic transformation kernel was then used for binary classification. Sample test results show that the prediction was ≥ 90% accurate. Note that classification accuracy can be improved with more true-to-life training data to cover more cases.

**ThuB1.5 11:00** ***A Skin Segmentation Method for Touchless Image Viewer in the Operating Room by 2D Camera***

Pichayapa Rungpanich (Srinakharinwirot University, Thailand); Paanchat Pattanaworapan (Laboratory School Centre for Educational Research And Development, Thailand); Kraiyot Kiatsoontorn (Dept. of Surgery, Thailand); Theekapun Charoenpong (Srinakharinwirot University, Thailand)

Contamination in operating room lead to infection in a patient specially during surgery. A touchless technology can be used to reduce contamination in the operating room when surgeon uses an X-ray image viewer. Skin segmentation is an important processing for touchless image viewer in an operating room. In this paper, we proposed a skin color segmentation method using threshold in color space. This method consists of three steps: 1) frame extraction, 2) color space conversion, 3) skin color segmentation. To test the performance of the proposed method, 601 images are used in the experiment. Accuracy rate is 50.46%. This is satisfactory for applying implementation algorithm for hand detection in future.

# ThuC1: Instrumentation and Smart Agriculture

Chairs: Sudchai Boonto (King Mongkut's University of Technology Thonburi, Thailand), Kanjanapan Sukvichai (Kasetsart University, Thailand)

**ThuC1.1 10:00** ***A Design and Development of a Pneumatic Shock Calibration Machine***

Krit Jiamjiroch, Thira Jearsiripongkul and Dahmmaet Bunnjaweht (Thammasat University, Thailand); Patchayaporn Doungkum (Pathumthani University, Thailand); Somthana Panyadilok and Adisorn Tongkum (Electricity Generating Authority of Thailand, Thailand)

Shock acceleration has been receiving attention to assess the impact resistance of products. The evaluation of the shock characteristics can be seen ranging from small size consumer electronics to large military equipment. The acceleration transducer, an accelerometer, plays an important role in shock measurement. The accelerometer must be calibrated to maintain the measurement accuracy and ensure its reliability. This work presents a design and development of a shock calibration machine based on ISO 16063-22. The pneumatic shock exciter was used to regulate air pressure to drive a projectile to strike an anvil to which accelerometers were mounted. The machine was applicable for an amplitude range of up to 9600 g. To support the calibration functionality, the electrical and pneumatic system control, data acquisition, and user interface were also implemented.

**ThuC1.2 10:15** ***The Development of Low-Cost Dry Electrode Using PDMS/CNT Composite***

Jongsook Sanguantrakul and Apit Hemakom (National Electronics and Computer Technology Center & National Science and Technology Development Agency, Thailand); Pasin Israsena (National Electronics and Computer Technology Center (NECTEC), Thailand)

The objective of this study was to develop the dry electrodes from polydimethylsiloxane (PDMS)/carbon nanotube (CNT) composite-based use for connected to traditional bio-signal instruments and presented their measurable monitoring capability, such as electroencephalogram (EEG), electromyogram (EMG), and interference signal, and biological compatibility. The proposed dry electrode advantages in wearable devices, flexible tattoo circuits, and stretchable displays has established a requirement for easily fabrication, strong durable, and low-cost materials. The performances of proposed dry electrode were evaluated by interference signal, electromyogram, and electroencephalogram measurement. In addition, the results of this study indicate that proposed dry electrode can be used to replace the commercial dry electrode, which can be applied in a variety of applications e.g. physical examination of medical vital signs, controlling intelligent devices and robots, and signal transmission through flexible material.

**ThuC1.3 10:30** ***Development of a Tomato Fruit Anomalies Detector for a Small Greenhouse Drone Application***

Sittiporn Tantiborirak and Kanjanapan Sukvichai (Kasetsart University, Thailand); Chanunya Loraksa (Huachiew Chalermprakiet University, Thailand)

Tomatoes are an important commercial crop. Tomatoes are popular in many parts of the world because they are easy to grow and have a high nutritional value. The fact that tomato fruits are prone to disease, even when grown in greenhouses, is a major challenge in large-scale tomato production. Agricultural drones are now being used to construct precision farming systems that can automatically detect irregularities in tomatoes. The main challenge with using a drone in a greenhouse is that the drone must be tiny enough to carry a restricted load, including an onboard computer. Because of this, the algorithm used to detect tomato fruit anomalies must be compact and efficient. The tomato fruit abnormalities detecting method was proposed in this research.

The method involved with CNNs and image processing algorithms. First the location of each tomato in tomato vines were identify and localized by using YOLOv4-tiny CNNs model, then, each tomato fruit was cropped. The background of the tomato fruit was removed by graph-like structure called GrabCut. Finally, all major defects were detected separately by the segmentation-based color thresholding technique. The experiments were conducted. The result showed that YOLOv4-tiny could detect tomato fruits with 98.68% AP and the color thresholding successfully detected the tomato anomalies.

**ThuC1.4 10:45** ***Implementation of a Monocular ORB SLAM for an Indoor Agricultural Drone***

Kanjanapan Sukvichai, Noppanut Thongton and Kan Yajai (Kasetsart University, Thailand)

Drones are increasingly being used in almost every major industry, including agriculture. Intelligent drone systems could enable precise agricultural. One of the critical uses of agricultural drone is to use in an automatic plant monitoring and inspecting. A drone must be tiny enough to fly between plants in order to capture images of plant trees or fruits in an indoor environment. Therefore, drone's payload is crucial because it limited onboard sensors weight. SLAM is necessary for autonomous navigation because it could provide all necessary information of drone navigation system without collisions. ORB SLAM was popular for monocular systems since it extracted ORB features from images to generate Visual Odometry. ORB SLAM generated the map as the output that can be used to estimate the position of the drone without the assistance of other sensors. In this research, monocular ORB SLAM system was proposed, explained and experimented in order to obtain and confirm the ORB SLAM performance for an indoor application. The experimental result showed that the ORB SLAM worked properly for generating a map of a tomato greenhouse and the output map could be used to estimate the drone position with some limitation.

**ThuC1.5 11:00** ***An Investigation of Surface Temperature Effect on Estrus Detection of Dairy Cows Using Supervised Learning***

Phongcharn Wongvivatvaitaya (King Mongkut's University of Technology Thonburi (KMUTT), Thailand); Rardchawadee Silapunt and Sudchai Boonto (King Mongkut's University of Technology Thonburi, Thailand)

This paper proposes an investigation of the surface temperature effect on the estrus detection of dairy cows using the supervised learning. The neck collars with temperature and motion sensors were attached to tested dairy cows. Four IP cameras were installed in the cow shed to monitor dairy cow behaviors and for data labeling. Neck temperature and motion data were collected and classified for behaviors and estrus prediction using 3 different supervised learning techniques: artificial neural network (ANN), Decision Tree (DT), and Random Forest (RF). By incorporating the neck temperature, the validation accuracies improved more than 25% compared to the control set, which comprised only motion data. In addition, the ANN technique provided higher validation accuracy than the DT and RF. The estrus prediction accuracy was 100% for all 3 techniques, 11% higher than that of the control set.

# Thursday, January 19 13:00 - 14:30

## ThuA2: ECTI-SICE Special Session on Advances in Control Engineering and Applications

Chairs: Sudchai Boonto (King Mongkut's University of Technology Thonburi, Thailand), Kou Yamada (Gunma University, Japan)

**ThuA2.1 13:00** ***Effects of Dimensionality Reduction on Classifier Training Time and Quality***

Auapong Yaicharoen (KMUTT, Thailand); Kotaro Hashikura, Md Abudus samal Kamal, Iwanori Murakami and Kou Yamada (Gunma University, Japan)

Two important aspects when training a classifier are being investigated, training time and classifier quality. Two well-known dimensionality reduction techniques are performed on three groups of data to create smaller data sets for classifier training. The first two techniques are the principal component analysis (PCA) and its modification called adaptive PCA (aPCA). The third

one is the linear discriminant analysis (LDA). Three groups of data sets are trained to create classifiers with and without being pre-processed with these feature reduction techniques. Training time and accuracy scores obtained from each classifier are compared, and the experiment results show that sample size and number of features are two important factors to be considered before selecting dimensionality reduction techniques. If the compatible data reduction technique and data set is chosen, the training time can be reduced without compromising the quality of the classifier.

**ThuA2.2 13:15** ***A Study on Reduction of the Number of Motion Control Motors of a Wheeled Snake Robot***

Yuuki Katou, Takaaki Hagiwara and Yuudai Kusano (Saitama Institute of Technology, Japan)

The motor for controlling the traveling direction of a wheeled snake type robot increases in order to improve the motion flexibility, and the control becomes complicated. In this study, for the purpose of the reduction of the number of motors for the motion control of the wheel type snake type robot, trial manufacture and examination of the wire steering in which the steering of multiple joints is possible for one motor were carried out. Though the control of the right and left turning motion could be carried out by the steering by the wire, the wire steering by the motor for up and down motion could not be carried out. It is considered that the trial manufacture and examination of the steering system for the purpose of the research on the trial manufacture and examination of the snake type robot for steering using the pulling force of the wire were completed.

**ThuA2.3 13:30** ***Matlab Platform Remote Control System Experiments***

Sungwan Boksuwan (King Mongkut's Institute of Technology Ladkrabang, Thailand)

The paper proposes the remote experiment that enables a student to conduct the physical control system experiment through the internet. The remote experiment is designed using MATLAB platform to create the user interface and to analyze the results. A DC motor controlled by PI controller is utilized as the physical system for demonstrating the effectiveness of the proposed system. Interface module with a dsPIC microcontroller is in charge of implementing a control loop and connecting between a user interface and a physical system. The experimental results reveal that there are a little delay times in live video monitoring but it does not affect the closed-loop control system and it can still be run in real time.

**ThuA2.4 13:45** ***Digital Retail Shop Services in Cyber-Physical Retail System: A Case Study of Food Business***

Chavapol Yensabai and Waranyu Ngoenthai (KMUTT, Thailand); Teema Leangarun (King Mongkut's University of Technology Thonburi, Thailand); Diew Koolpiruck (KMUTT, Thailand)

Food demand is expected to grow substantially as a result of major factors such as population. It necessitates that food manufacturers streamline their supply chain to accommodate shorter product life cycles. To manage sustainable food solutions and successful supply chain management, cyber-physical systems at the supply chain level attempt to challenge the integration of data from suppliers, manufacturing, logistics, and retail. The implementation of Cyber-Physical Retail Systems (CPRS) was developed to sense and analyze dynamic market environments to modify sales and shop operation activities. The data were collected from several ERP modules and operational technology (OT) data. The shop CPS was managed using the OSIsoft-PI platform, which is based on service-oriented architecture (SOA) and then integrated into the Enterprise Cloud. The customer analytics service in CPRS was used as an example of a self-aware concept to notify the sales function and was implemented on the Azure platform. The results show that churn prediction in retail shops can be detected monthly for warning sales staff based on the customer object goal.

**ThuA2.5 14:00** ***The Study of Sementic Deep Learning Segmentation for Durian Orchard***

Sungwan Boksuwan (King Mongkut's Institute of Technology Ladkrabang, Thailand)

The paper comparatively studies a deep learning based semantic segmentation for segmenting durian orchard environments using MATLAB platform. Experiments consist of four treatments that are the combinations of Deeplabv3+ with base networks including Resnet-18, Resnet-50, Xception and Interceptionresnetv2. IoU metric is utilized as the performance index. The environment is segmented into five classes. The experimental results tested by ANOVA reveal that base networks do not result in a different performance for the class of sky, tree, grass, and road but show different performance for background class.

**ThuA2.6 14:15** ***Crop Prediction Based on Soil Nutrients Using Fuzzy Approach***

Swathi T (National Institute of Technology Tiruchirappalli, India); Selvaraj Sudha (National Institute of Technology, Tiruchirappalli, India)

Nutrients in the soil is the main impact for crop growth. Presently, the farmers cultivate either the traditional crop or crop in demand without analysing the suitability of soil nutrition. This may result in poor yield, leading to stress and low income. Adding excess fertilizers can lead to poor yield and also contaminate the underground water. Considering these factors, a fuzzy logic controller is designed to predict the crop that is suitable based on the availability of soil nutrients. The proposed Fuzzy logic controller involves two fuzzy blocks, each with different inputs and the output is six different crops. The fuzzy logic system receives inputs such as nitrogen, phosphorus, potassium, and sulphur levels, pH, and Electrical Conductivity. The output is six crops namely pomegranate, mango, grapes, mulberry, ragi, and potato. Finally, the two fuzzy blocks are combined using the Simulink software for a particular crop Prediction.

# ThuB2: Artificial Intelligence II

Chairs: Kitsuchart Pasupa (King Mongkut's Institute of Technology Ladkrabang, Thailand), Somying Thainimit (Kasetsart University, Thailand)

**ThuB2.1 13:00** ***The Machine Learning-Based Algorithm for Solving Inverse Kinematics of the Robot Manipulator***

Byeong Jun Kim (Yeungnam University, Korea (South)); Won Yeol Yoon (Yeungnam University & Intelligent Control and Automation System Lab., Korea (South)); Nam Kyu Kwon (Yeungnam University, Korea (South))

This paper presents a machine learning-based algorithm for obtaining the solution of inverse kinematics of a robot manipulator. In this paper, OpenManipulator-X with 4 degrees of freedom is used as the robot manipulator, and the database for applying the machine learning model to the controller is created using MATLAB. The database is built in the form of acquiring the kinematics pose according to the joint position, and these are used as input and output data for learning, respectively. The joint position has four joint angles of the robot manipulator, and the kinematics pose has seven values including the position in configuration space and quaternion of the end-effector of the gripper. The suggested machine learning models are trained and evaluated to predict the correct joint position with the built database. Finally, this paper successfully shows the reliable validity of the proposed algorithm by comparing and analyzing the performance of the machine learning model for improving problems of the analytical model for solving inverse kinematics.

**ThuB2.2 13:15** ***Bleeding Region Segmentation in Wireless Capsule Endoscopy Images by K-Mean Clustering Technique***

Areeya Seebutda (Srinakharinwirot University, Thailand); Sirilak Sakuncharoenchaiya (srinakharinwirot university, Thailand); Nuwee Wiwatwattana (Srinakharinwirot University, Thailand); Amber Charoen (Johns Hopkins University Maryland, USA); Kawee Numpacharoen (Georgia Institute of Technology, USA); Theekapun Charoenpong (Srinakharinwirot University, Thailand)

Wireless capsule endoscopy (WCE) is used to record internal images of the gastrointestinal tract. A common symptom such as gastrointestinal bleeding can be diagnosed by images. In this paper, we proposed a method for bleeding region in gastrointestinal segmentation by the K-Mean Clustering technique. The images were captured by WCE. This method consists of three steps: preprocessing, color clustering, and bleeding region segmentation. Firstly, input data in RGB color space is converted to L*a*b color space. Color intensity has two cluster which is bleeding region, and background. The K-Mean technique is used to group the data. Finally, bleeding region is defined by intensity in red layer. In experimental result, 48 images from kid database are used. The accuracy rate is 84.26%, DICE rate is 67.71%, Jaccard Index (JI) is 60.43%, sensitivity rate is 69.84% and the precision rate is 65.70%. The results is satisfactory for future improvement

**ThuB2.3 13:30** ***Teeth Detection for Panoramic Dental X-Ray Image by Rotated Tooth Template for***

***Telemedicine Technology***

Nirunchara Sirinart, Wanwisa Paton, Piyamaporn Wareethip and Theekapun Charoenpong (Srinakharinwirot University, Thailand)

Telemedicine technology is important for rural area or underdeveloped countries. Panoramic dental x-ray image is used to diagnosis impacted tooth. A process to diagnosis impacted tooth is teeth detection. In this paper, we proposed a method for teeth detection by rotated tooth template. This method consisted of template preparation and image correlation computation step. Template of teeth is varied in the range of 0-360 degrees for detection impacted tooth. Correlation ratio between template and test image is computed. Correlation ratio over threshold is defined as teeth. To test the performance of the method, fifty images are used. Based on the results, both normal tooth and impacted tooth can be detected. This method prove that the rotated tooth template has potential to detection impacted tooth.

**ThuB2.4 13:45** ***Real-Time Image Processing for Production Tracking in Manufacturing Plant***

Koksal Chou (Institute of Technology of Cambodia, Cambodia); Chawalit Jeenanunta (Sirindhorn International Institute of Technology, Thailand); Wetu Vexo (Thammasat University, Thailand); Apinun Tunpan and Nisit Sirimarnkit (SMART Sense Industrial Design, Thailand); Tith Vong (Sirindhorn International Institute of Technology, Thailand); Kosorl Thourn (Institute of Technology of Cambodia, Cambodia)

Tracking the number of work-in-process (WIP) and finished goods is a big challenge in factories. Additional workers are required to perform this task. It is a tedious and error-prone task for the workers. The production planners need to add additional finished goods to their production schedules to account for unknown mismatched production, which wastes a lot of money, workforce, and time in manufacturing. In recent years, there has been an advancement in computer vision, such as object recognition and detection. This research proposes a method using image processing to count the WIP in safety shoe manufacturing. This technique combines Yolov4-tiny as a detection engine and Deepsort algorithms along with OpenCV to track, count, and classify products for a real process in a factory. Special regions are assigned in the video frame to count the shoes and bad-quality shoes. The experiment is demonstrated on 5 videos streaming from the CCTV inside the factory. The results have shown that besides the blurry streaming, the proposed algorithm can track and classify both categories of shoes effectively.

**ThuB2.5 14:00** ***Robot Arm Movement Control by Model-Based Reinforcement Learning Using Machine Learning Regression Techniques and Particle Swarm Optimization***

Kittipong Boonlong (Burapha University, Thailand)

Robot arms are machines which are not only used in industrial technologies but also other applications such as medicine and agriculture. The robot arm movement control is important in the use of robot arms. This paper presents model-based reinforcement learning (MBRL) in robot arm movement control in case studies where targets are in random positions. The numerical studies of two arms and three arms robots moving in planar motion are used as test problems. In two arms robot control, 2 tasks - placing and reaching are employed. In three arm robot control, noise is considered. Machine learning regression techniques - gaussian process regression (GPR), artificial neural network (ANN), and support vector regression (SVR) - are used in environment modelling in MBRL while particle swarm optimization (PSO) is used as optimization tool in MBRL. The numerical studies show that MBRL with GPR has the highest performance with at least 95% success rate while MBRL with the other regression techniques such as ANN and SVR can succeed only 23-93% and 31-47%, respectively. Therefore, MBRL with GPR and PSO is suitable for robot arm movement control.

# ThuC2: Control Theory , Automation and Control Applications

Chairs: Benjamas Panomruttanarug (King Mongkut's University of Technology Thonburi, Thailand), Witthawas Pongyart (King Mongkut's University of Technology North Bangkok, Thailand)

**ThuC2.1 13:00** ***Intelligent Sliding Mode Control of Active Power Filter Using Extended State Observer***

Juntao Fei (Hohai University, China)

A fuzzy neural network adaptive sliding mode control with a self-feedback recursion(FNNASMC-SFR) based linear extended state observer (LESO) is proposed for a single-phase active power filter (APF), where the adaptive sliding mode controller is designed to improve the response and accuracy of compensation current tracking the reference current. The LESO is designed to estimate the actual APF system dynamics which includes the parameter perturbation and external disturbance. Moreover, the fuzzy neural network with self-feedback recursion is adopted to mimic the switching control gain of ASMC, which combines the output values of neurons at the current time and the previous time, to achieve better dynamic approximation effect and prevent sudden changes. Hardware experiments verify the introduced method is a viable control solution in harmonics suppression and current control.

**ThuC2.2 13:15** ***A Gradient Descent Method for Optimal Batch-To-Batch Control of Unknown Linear Systems***

Yuanqiang Zhou and Xiopeng Tang (Hong Kong University of Science and Technology, Hong Kong); Furong Gao (HKUST, Hong Kong); Xin Lai (University of Shanghai for Science and Technology, Hong Kong); Dewei Li (Shanghai Jiao Tong University, China); Weiguo Ma (Nantong University, China)

This paper discusses optimal batch-to-batch (B2B) control problems and presents a gradient descent method solution for unknown linear batch process systems. Using historical process data, we design a model-free method for B2B optimization that eliminates the need for model information about the system. By using quadratic programming (QP) to formulate the optimal controller design, we first present the optimal iterative learning control (ILC) results. Next, using the gradient descent method, we replace the uncertain term with the actual measurements and develop a new ILC approach based on convex hull representations of uncertain realizations. As compared to the norm-optimal ILC, our proposed ILC can guarantee superior performance with reasonably selected parameters. Finally, we demonstrate our design with an illustrative numerical example.

**ThuC2.3 13:30** ***Three-Phase Inverter Using Robust Tracking Control Based Interpolation***

Vichet Huy (Electricity of Cambodia, Cambodia); Heng Tang and Panha Soth (National Polytechnic Institute of Cambodia, Cambodia); Socheat Yay and kakada Sovan (NPIC, Cambodia); Chivon Choeung (National Polytechnic Institute of Cambodia, Cambodia)

This paper presents a new method to determine the control inputs and control gains of robust tracking control-based interpolation control. To obtain the proposed control input, the implement two different types of control gains is needed, tight and loose gains. A linear matrix inequality (LMI) is considered with input constraint, feasibility, and invariant sets to define the control inputs of tight gain and loose gain in the sense of robust tracking control. Thus, in simulations, if the control input of tight gain satisfies the input constraint, no interpolation is needed. Then, the tight control can be used directly to start the inverter system. In contrast, if the control input with tight gain is infeasible then the implementation of a new technique is needed to define the control input based on tight and loose control gains. By interpolating between these two control inputs, a new set of control input which is called interpolation-based control is created. Finally, by using the interpolation an exceptional performance is yielded for the output response, satisfies with input constraint, and has a broad enough size of invariant set. In this work, a MATLAB, PSIM simulation is conducted to verify the efficacy of the control algorithms.

**ThuC2.4 13:45** ***Object Classification by Spectrogram Analysis of Impact Force Response Using Convolution Neural Network***

Krittapart Rattanasuwan and Chowarit Mitsantisuk (Kasetsart University, Thailand)

The object classification is widely used for many industrial application areas. There are many researchers try to develop a new classification method. A signal can carry data about virtually anything from sound picture video and text data. For example, sound is converted into electrical signals by using microphone. However, sound signal contains a lot of noise. To solve this problem, we proposed to use impact force response for object classification. In this research, impact force response signal is estimated from the interaction between object and robot system by using disturbance observer. It will be depended on size, material type stiffness and flexibility of the object. The characteristic of signal is applied to classify object by using the Convolution Neural Network (CNN). There are two step for our proposed algorithm. The first step is to create spectrogram images from impact force response to improve performance and accuracy of classification. The second step is to use CNN to classify objects. As shown in the experimental results, it can be achieved accuracy rate about 96%, precision rate 93%, and recall rate 84%.

**ThuC2.5 14:00** ***On the Modeling and Simulation of a Saturated SIR Epidemic Model with Joint Vaccination of Newborns and Susceptible Subpopulations***

Manuel de la Sen (University of the Basque Country, Spain)

This paper presents and studies a new epidemic SIR (Susceptible-Infectious-Recovered) model with susceptible recruitment and eventual joint vaccination efforts on newborn and susceptible individuals. Saturation effects in the incidence terms are eventually assumed for both the Infectious and the Susceptible. The vaccination action on newborn individuals is assumed to be applied to a fraction of them while that on the susceptible general population is of linear feedback type, based on information on the current levels of the Susceptible. The basic reproduction numbers (i.e. the numbers of average contagions on the Susceptible from each Infectious) are shown to decrease with the application vaccination control efforts, which implies that the allowed disease transmission rates compatible with the local stability of the disease-free equilibrium point increase under such controls.

# Thursday, January 19 14:45 - 16:00

## ThuA3: Robotics

Chairs: Kanjanapan Sukvichai (Kasetsart University, Thailand), Kittipong Yaovaja (Kasetsart University, Thailand)

**ThuA3.1 14:45** ***Parameter Identification of a Robot Manipulator with Nonlinear Friction Model***

Woraphrut Kornmaneesang (Yuan Ze University, Taiwan); Chen Shyh-Leh (National Chung Cheng University, Taiwan)

This paper proposes a novel parameter identification method for the robot manipulator with a nonlinear friction model. The dynamic parameters are divided into linear and nonlinear sets. The inverse dynamics model is reduced into a form linear in relation to the linear set, while the nonlinear set remains in the observation matrix. A global optimization technique with the LS method can be used to identify the dynamic parameters. The effectiveness of the proposed identification method is highlighted through experiments carried out by a 5-DOF robotic experimental platform. The results show that the proposed method outperforms the standard one, since the identification results are limited by the linear friction model.

**ThuA3.2 15:00** ***Design and Development of Navigation System for an Autonomous Vehicle***

Benjamas Panomruttanarug (King Mongkut's University of Technology Thonburi, Thailand); Thanakorn Ketnoi, Ashis Kumar Ojha and Natthawut Boonruam (KMUTT, Thailand)

Soon, autonomous vehicles will become a reality. Many tech companies and automakers are competing to develop their prototypes with the expectation of becoming the first company that could launch a fully autonomous car. To demonstrate a self-driving car, this work presents a design and development of an autonomous vehicle modified from an electric golf cart and demonstrates the lateral tracking control based on a PID controller. Having level 2 autonomy, our autonomous golf cart can control steering, speed, and braking under a take-over control action requested by the driver. To reach level 3 autonomy, the autonomous golf cart gives a demonstration for testing navigation and tracking control. GNSS positioning data obtained from the RTK modules are used to manually create the desired path while driving the vehicle. For the automated driving test, a PID controller is used in the lateral tracking control system to control the golf cart to follow two straight paths in the experiment. The results show that the vehicle can smoothly track the desired path.

**ThuA3.3 15:15** ***Asynchronous and Synchronous Federated Learning-Based UAVs***

Itika Sharma and Ayushe Sharma (Shri Mata Vaishno Devi University, India); Sachin Kumar Gupta (Shri Mata Vaishno Devi University (SMVDU), Katra, J&K, India)

Unmanned aerial vehicles (UAVs) can be used to support data gathering, training of models, and wireless communication by acting as flying Base Stations (BSs). The usage of UAVs for wireless networks is quickly expanding in areas such as tracking

as well as surveillance, defense, leading healthcare deliveries, telecommunications, and so on. As Deep Learning (DL)-assisted approaches require sending raw data from model training devices to UAV servers which is problematic because of device privacy concerns and UAVs' limited processing or communication resources. Federated Learning (FL), which is also called distributed deep learning, is presented as a solution, with the core notion of keeping original or raw data where it is created while transferring the only user's localized trained DL models to a centralized organization for aggregation. We will build a Synchronous Federated Learning (SFL) structure for multi-UAVs and also the comparative analysis of Asynchronous Federated Learning (AFL) and SFL. The SFL methodology will take some time to execute, but there will be no data loss or packet loss. AFL, on the other hand, takes less time but results in packet data loss. Simulation findings suggest that our proposed framework and technique improve global rounds and learning accuracy as compared to AFL.

**ThuA3.4 15:30** ***A Comparative Study of Vehicle Platoon with Limited Output Information in Directed Topologies***

Agung Prayitno (University of Surabaya & Indonesia, Indonesia); Veronica Indrawati (University of Surabaya, Indonesia); Itthisek Nilkhamhang (Sirindhorn International Institute of Technology, Thammasat University, Thailand)

This paper aims to study and compare the effect of limited-output information in various directed topology to the performance of vehicle platoon. Two distributed controllers based on limited-output information will be compared to cooperative state variable feedback control which designed based on full-state information. The comparison will be conducted for four common directed topologies in the vehicle platoon application. Simulation analysis is performed in three scenarios, namely under normal operations, when the leader moves with constant acceleration and when the platoon is subjected to constant communication delay. Performances comparison will be observed from inter-vehicular distance response in each follower and the results will be displayed with respect to the follower vehicle index in the platoon configuration. Finally, the behavior of each control scheme in various topologies will be summarized.

**ThuA3.5 15:45** ***Experimental Instrument for Studying Scaled Tire's Slip-Friction Characteristics***

Ronnapee Chaichaowarat and Sirawich Wongwaisayawan (Chulalongkorn University, Thailand)

This research aims to design and develop a new experimental instrument that can test a scaled wheel in any desired scenario. In this paper, the scenario will be the scaled wheel dynamic during braking. Since the common cause of car accident is the inability to brake the vehicle in time by the driver. Hence, the research will focus on pinpointing the maximum braking force at a certain slip ratio. However, due to the limited access to high-precision apparatus, only the experimental instrument and the testing of the braking system design are achieved. Hence, the main outcome of the project is to validate that the relationship between the wheel dynamic and forced occurred during braking can be studied through the project design and can be used to create future improvement based on the system for commercial use.

# ThuB3: Special Session on Data Science and Artificial Intelligence for Disaster Risk Reduction

Chairs: Natt Leelawat (Chulalongkorn University, Thailand), Jing Tang (Chulalongkorn University, Thailand)

**ThuB3.1 14:45** ***The 2022 Rayong Oil Spill Crisis in Thailand: An Identification for Reliability and Nearly-Real Time Data Using Twitter***

Kumpol Saengtabtim (Chulalongkorn University, Thailand); Ampan Laosunthara (Information Systems Research Group, Thailand); Jing Tang and Natt Leelawat (Chulalongkorn University, Thailand)

The oil spill is considered to be a crisis that caused a lot of impact on the marine environment. At the beginning of 2022, an oil spill crisis happened in Rayong Province, Thailand. This crisis caused more than 140 barrels of leakage. During the crisis, Twitter was one of the leading social media many people shared and posted news related to the situation. In this research, the analysis based on the content from Twitter for defining the reliability and nearly-real-time properties of Twitter has been performed. The cosine similarity has been selected to be the methodology to find the similarity for the Part of Speech (POS) between the contents from

verified and non-verified Twitter accounts for proving the reliability property. The results of the analysis show that the contents posted on Twitter platform have timeliness property due to the increasing amount of the tweets posted since the beginning of the crisis. For the reliability property of Twitter, it can be proved by the high similarity value for nouns and adjectives tagged between the contents from verified and non-verified accounts.

**ThuB3.2 15:00** ***Status of Industrial Complex Activity Explained by Air Quality: Central Thailand***

Akira Kodaka (Keio University, Japan); Natt Leelawat and Jing Tang (Chulalongkorn University, Thailand); Yasushi Onda and Naohiko Kohtake (Keio University, Japan)

Business continuity in industrial complexes is linked to a local economy. To assess urban resilience, it is necessary to incorporate the activity of the complexes, but limited method has been established. To answer the research question of whether changes in the concentration of air composition substances can explain the industrial complexes activity, this study focused on several industrial complexes located in the central region of Thailand and conducted an analysis of changes in PM2.5 and NO2 concentrations and the expected activity trends of industrial complexes under COVID-19. As a result, it was confirmed that the situation of the industrial complexes whose activities were reduced by the pandemic and the decreasing trend of each concentration were in synchronization. This proves that the concentration of air composition substances has a potential to explain the activities of the industrial complexes. For further study, more specific causal inferences should be applied by extracting characteristics such as other air composition substances, and industrial complexes including the number of companies and major industries, to enhance the potential.

**ThuB3.3 15:15** ***Inertial and Magnetic Measurement Unit-Based Orientation Estimation Using a Parallel Neural Network***

Ji Seok Choi, Chang June Lee and Jung Keun Lee (Hankyong National University, Korea (South))

Three-dimensional orientation estimation using inertial and magnetic measurement unit (IMMU) is of key importance in inertial motion capture system. As an alternative to conventional filter algorithms, this study proposes a parallel neural network which is composed two recurrent neural networks (RNN) separately estimating attitude and heading vectors. Then, a complete 3D orientation in terms of direction cosine matrix can be determined. The advantage of the proposed neural network is that it can minimize attitude and heading errors caused by the various disturbance components. After the training process, the proposed neural network showed better estimation performance than the conventional filters under various disturbance conditions.

**ThuB3.4 15:30** ***Investigation on MLP, CNNs and Vision Transformer Models Performance for Extracting Human Emotions via Facial Expressions***

Aomsup Panlima and Kanjanapan Sukvichai (Kasetsart University, Thailand)

Artificial Intelligent or AI plays an important role in many applications in many fields. One of the difficult challenges in AI development is to make machine understand the human feeling through expressions because human expression can express through various ways, for example, voices, facial actions, behaviors or directly from the brain signals. This knowledge is useful for diagnosing situations where patients lie about their symptoms. In this research, Facial Emotion Recognition or FER is mainly focus. Deep Neural Network (DNNs) or Multi-Layers Perceptron, Convolutional Neural Network (CNNs), combine both DNN and CNN, Vision Transformer models were applied to extract the human emotion via face expressions data from AffectNet, Tsinghua, CK+, KDEF and RAF face datasets. The experiments were experimented, and result was compared. Finally, all models were evaluated on the testing dataset to confirm their performances. The result revealed that the Vision Transformer model has outstanding performance than other models.

# ThuC3: Power Control and Energy Systems

Chairs: Komsan Hongesombut (Kasetsart University, Thailand), Wanchak Lenwari (KMUTT, Thailand)

**ThuC3.1 14:45** ***The Electricity Generation from Rice Flour Wastewater by a Single Chamber Microbial Fuel Cell in Continuous Mode Operation***

Sarawut Suphannarach (Kasetsart University, Thailand); Dusit Thanapatay (Kasat. Univ, Thailand);

Nattakarn Prasertsung (Kasertsart University Chalermprakait Sakonnakorn Campus, Thailand)

This paper presents a single chamber microbial fuel cell (SCMFC) in continuous mode operation and a self-start-up boost converter circuit. This system is powered by wastewater synthesized from rice flour powder. The SCMFC in continuous mode operation, by using the organic loading rate (OLR) in the research of 0.91kg/m-d, and the 3L/day flow rate of wastewater. The proposed boost converter circuit structure consists of two stages, the first stage is a self-oscillator for start-up capability with low-input voltage, and the second stage is an energy harvesting, voltage regulating, and energy storage circuit. For the 54uW, 0.485V input of SCMFC, it takes 19.5 hours to charge the storage supercapacitor to 5.25V which can produce a 3.3 V output at the LTC3588 IC module. Moreover, the efficiency of the chemical oxygen demand (COD) removal is 24.97% and the efficiency of suspended solids (SS) removal is 96.34% of OLR.

**ThuC3.2 15:00** ***Modeling Li-Ion Battery Using Measurement Data***

Tanapon Yutthanava (KMITL, Thailand)

A precise battery model is essential for battery management system to predict state of charge and cell balancing. The aims of this paper are improved Lithium-ion battery model and study behavior of Lithium-ion battery. In this paper a second-order equivalent circuit of battery lithium-ion is developed to use for Lithium-ion Nickel based battery. The model is developed and validated with experiment result in MATLAB/SIMULINK/SIMSCAPE, As the comparison, The developed model is capable to predict current-voltage performance accurately in battery management system.

**ThuC3.3 15:15** ***Linear Matrix Inequality-Based Optimal State Feedback Control of a Three-Phase L-Filtered Grid-Connected Inverter***

Chivon Choeung, Heng Tang, Panha Soth, Sothim Keo, Phearit Leang and Horchhong Cheng (National Polytechnic Institute of Cambodia, Cambodia); Sarot Srang (Institute of Technology of Cambodia, Cambodia); Vichet Huy (Electricity of Cambodia, Cambodia)

This paper discusses a systematic control design for a three-phase L-filtered grid-connected inverter using linear matrix inequality-based optimization method. A state feedback control is employed to provide stability to the inverter system and with the inclusion of integral control the offset error can be eliminated. In addition, the proposed control is implemented in dq-synchronous frame with help from a phase locked-loop to track the grid phase angle. The optimization criterion of this proposed control is to reduce the convergence time to the steady state as short as possible. The set of robust stabilizing gain is systematically discussed in this paper and computed using MATLAB toolbox. Then, the effectiveness of this proposed control algorithm is verified by implementing on PSIM simulation tool.

**ThuC3.4 15:30** ***Modeling and Analysis of 300 MW Photovoltaic System Using ETAP***

Mehrauz Rehmat (Dawood University of Engineering and Technology Karachi, Pakistan); Arsalan Ansari (Shahrah e Faisal & Dawood University of Engineering & Technology, Karachi, Pakistan); Maqsood-ur-Rehman Rehman (Dawood University of Engineering and Technology Karachi, Pakistan)

Electricity is important in our life. The majority of electricity are generated by using fossil fuel. There are various drawbacks linked with the use of fossil fuel such as emission of greenhouse gases which pollute the environment. Among all renewable energy systems, the solar photovoltaic (PV) system has remarkable results to overcomes these problems due to its availability, cheap and environment friendly. In this paper, 300 MW photovoltaic power system is designed and modeled on Electrical Transient Analysis Program (ETAP). The proposed system consists of 4 strings of photovoltaic arrays and each string of PV array is made up of 27 series connected panels and 9000 parallel connected panels. ETAP is used to perform power flow analysis and harmonic distortion analysis. Also, single-tuned passive filters are designed to reduce the effects of harmonics.

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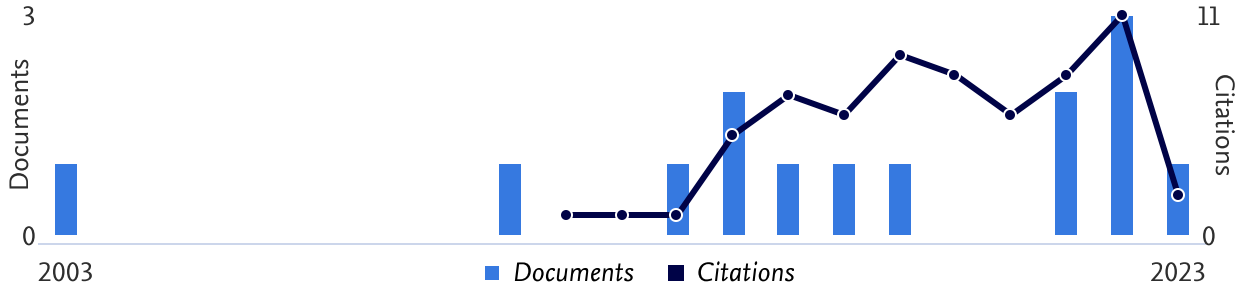


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