RESEARCH DIGEST

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Features

Special feature of
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Issue 4

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Office of Research and Development, National Cheng Kung University
email: em50900@email.ncku.edu.tw
TEL: 06-2757575#50900
FAX: 06-2766462

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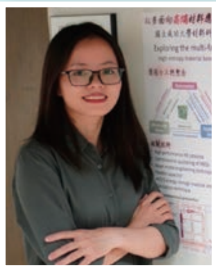
High Entropy Promoted Active Site in Layered Double Hydroxide for Ultra-Stable Oxygen Evolution Reaction Electrocatalyst


Jyh-Ming Ting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Jyh-Ming Ting,
Distinguished Professor

Team Introduction

Dr. Jyh-Ming Ting is a Professor at the Department of Materials Science and Engineering, National Cheng Kung University (NCKU) in Taiwan. He holds a BS degree in Nuclear Engineering from National Tsing Hua University, Taiwan, and MS and PhD degrees at the Department of Materials Science and Engineering, University of Cincinnati. After Dr. Ting received the PhD degree, he joined Applied Sciences, Inc. (AS), Ohio, USA as a Scientist and then the R&D Director, working of carbon and diamond materials. After 8-year of working at ASI, Dr. Ting accepted a faculty position in NCKU where he continued his research in carbon-related materials. In the meantime, Prof. Ting also worked on functional thin film and powder ceramic materials, In recent years, he has further explored various high entropy ceramics useful as catalysts in water electrolysis for green hydron generation, as well as pollutant degradation and energy storage devices. Prof. Ting has received a number of awards, authored over 200 refereed journal articles, and holds more than 30 patents.

Oxygen evolution reaction (OER), a half-cell reaction involved in electrochemical water splitting and metal-air battery, limits the efficiency of these energy conversion systems due to its sluggish reaction kinetics [1]. To accelerate the OER, highly efficient electrocatalysts are required. Currently, large-scale commercial systems use precious metal-containing catalysts, e.g., RuO_2 and IrO_2, baring their high cost, instability, and low abundance [2, 3]. For practical applications, a large current density is highly desirable. However, most of the non-precious metal-based OER electrocatalysts are unstable at a current density higher than 200 mA cm^{-2}, which is a vital restriction for large-scale productions [4, 5]. Hence, the development of cost-efficiency and earth-abundance metal-based electrocatalyst with high OER electrocatalytic activity and long-term electrochemical stability is called for.

Recently, a new class of materials consisting of at least five homogeneously-distributed metal elements, namely high entropy material (HEM), has emerged and continues to draw huge attentions theoretically and experimentally. HEM demonstrates its highly promising role via offering infinite possibilities to regulate the electronic structure and electrical property for optimized catalytic performance. The unique HEM is also capable of providing abundant catalytic active sites for the reaction and enhances the stability [25]. Inspired by such unique characteristics, various HEMs, such as alloys, fluorides, oxides, sulfides, phosphides, metal organic frameworks, *etc*. have been investigated [26-32]. Wang *et al.* prepared (Co, Cu, Fe, Mn, Ni)$_3$O$_4$ high entropy oxide (HEO) via a solvothermal method [27]. The HEO was used as OER electrocatalyst which achieves a current density of 10 mA cm^{-2} at 1.58 V in 1 M KOH. Cui *et al*. reported the synthesis of high-entropy metal sulfide, i.e., (CrMnFeCoNi)S$_x$, and showed an overpotential of 295 mV at 100 mA cm-2 and good durability with slightly polarization after 10 h [33]. A high entropy phosphate, i.e., CoFeNiMnMoPi, was reported to have a low overpotential of 270 mV at 10 mA cm^{-2} and Tafel slope of 74 mV dec^{-1} [34]. In this study, high entropy concept is used to prepare high entropy layered double hydroxide (LDH)sfor use as OER electrocatalyst. The LDH was designed to consist of five consecutive non-noble metals of Fe, Ni, Co, Mn, and Cr in the periodic table, and grown on a Ni foam via a simple hydrothermal method.

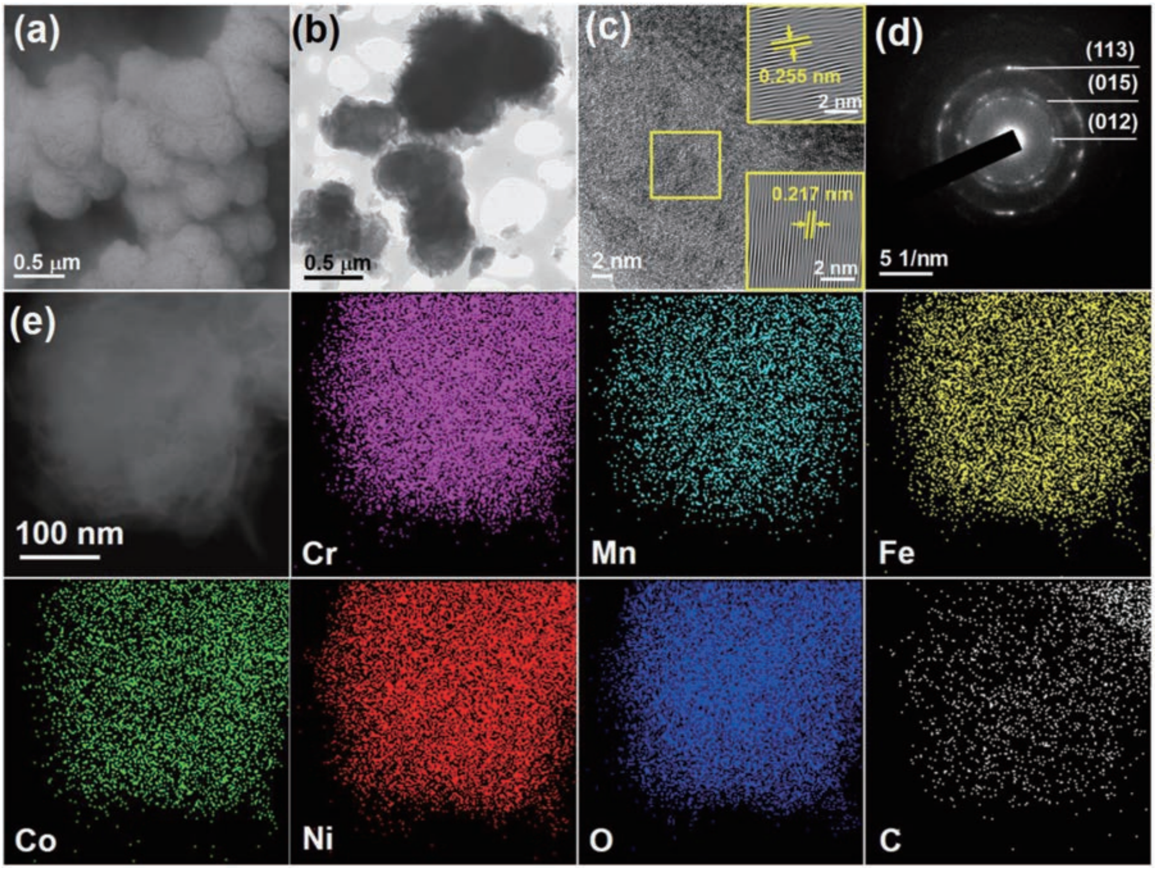

Figure 1. (a) SEM, (b) TEM, and (c) HRTEM images with the insets showing IFFT images of the FeNiCoMnCr. (d) SAED pattern, and (e) HAADF image and STEM-EDS elemental mappings.

The quinary FeNiCoMnCr LDH shows a flower-like morphology (Figures 1a and b). Figure 1c shows HRTEM image, with the insets of inverse fast Fourier transform (IFFT) images, giving lattice spacings of 0.255 and 0.227 nm that belong to the (012) and (015) planes of LDH (JCPDS#40-0215), respectively. SAED diffraction rings shown in Figure 1d are well indexed to LDH structure. HAADF image and STEM-EDS elemental mappings (Figure 1e) show that all the elements have homogeneous distributions.

Polarization linear sweep voltammetry (LSV) curves are shown in Figure 2a. The overpotential at a current density of 50 mA cm^{-2} (η_{50}) and TOF values at an overpotential of 250 mV are presented in Figure 2b. The FeNiCoMnCr exhibits a superior OER activity with a remarkably low overpotential of η_{50} = 218 mV, which is 29, 55, 70, 171, and 191 mV less than that of the FeNiCoMn, FeNiCo, FeNi, IrO_2, and HT-Ni foam catalysts, respectively. The FeNiCoMnCr supported on Ni foam also demonstrates the highest

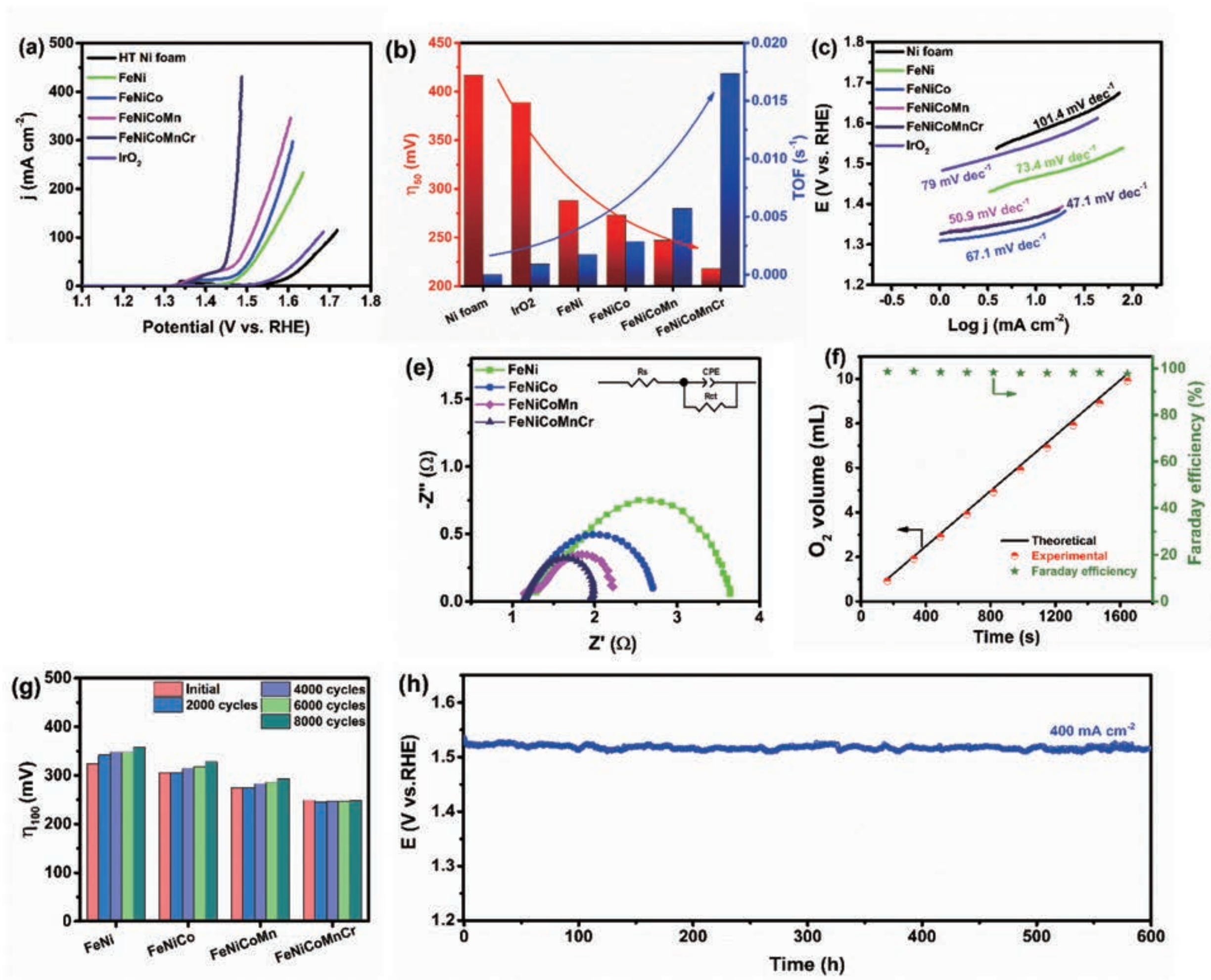

Figure 2. (a) LSV polarization curves, (b) overpotential at 50 mA cm^{-2} and TOF at an overpotential of 250 mV (c) Tafel plots, (e) Nyquist plots of the as-prepared LDHs. (f) Measured O2 generation at 100 mA cm^{-2} and the associated FE, (g) overpotential at 100 mA cm^{-2} after various cycles, and (g) chronopotentiometric E-t curve at 400 mA cm^{-2} for 600 h of the FeNiCoMnCr.

TOF value of 0.0173 s^{-1}. Figure 2c shows the Tafel slopes which derived from the LSV curves. The electrochemical impedance characteristics of the electrocatalysts are examined via the Nyquist plots shown in Figure 2e. The calculated FE of the high entropy FeNiCoMnCr LDH catalyst is more than 97% (Figure 2f). Figure 2g shows the overpotentials at 100 mA cm^{-2} of various LDHs after different cycles. Almost no activity decay is seen in the FeNiCoMnCr. The long-term operating durability at a high constant current density of 400 mA cm^{-2} is shown in Figure 2h. Significantly, the FiNiCoMnCr electrocatalyst shows an outstanding durability with a negligible potential increase for a long time of 600 h.

In summary, we have prepared a high entropy LDH rooted on Ni foam of FeNiCoMnCr, as high-efficient and superior-stability electrocatalyst for OER in water splitting. The catalyst demonstrates outstanding OER performance, with a low overpotential of 218 mV to achieve a current density of 50 mA cm^{-2} and a small Tafel slope of 47.1 mV dec^{-1}, outperforming its binary, ternary, and quaternary metal counterparts, and many reported electrocatalysts. At a very high current density of 400 mA cm^{-2}, the electrocatalytic performance of FeNiCoMnCr is well maintained for an ultra-long duration of 600 h. The interaction among the multi-metal components along with the electronic structure modulation accelerates the formation of high-active high valency γ-NiOOH species, drastically boosting the electrocatalytic activity. The DFT calculation further supports the experimental data.

Acknowledgement

This work was supported by the Ministry of Science and Technology in Taiwan under Grant Number MOST 111-2224-E-006-005. The use of [EM000800] JEOL JEM-2100F Cs STEM in the Core Facility Center of National Cheng Kung University is acknowledged.

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Brave the Challenge and Embrace Science with Enthusiasm!

—— I-Son (Grace) Ng,
Professor

Author Introduction

Professor I-Son (Grace) Ng from the Department of Chemical Engineering became the first female awardee of the Outstanding Research in the field of Chemical Engineering from National Science and Technology Council (NSTC). Professor Ng is devoted to research using synthetic biology, which relies on the “Design-Build-Test-Learn" cycle to create the best chassis for chemical production, especially toward carbon net-zero emission. Her impact is not only in the university, but also extends to social responsibility, as her achievements contribute to realizing the sustainable development goals (SDGs).

Professor Ng leads the "Functional Genes and Proteomics Laboratory", which aims to achieve carbon neutrality and produce high-value chemicals by exploring new genes, optimizing pathways, and establishing new technologies. With the rise of sustainable development goals, chemical engineering has entered a new era of green manufacturing, presenting an opportunity to engage in the Fourth Industrial Revolution. Additionally, responding to climate change and greenhouse gas effects, zero emissions and carbon neutrality technologies have become globally significant issues in recent years. Professor Ng and her group have achieved several accomplishments as follows:

Awards, Achievements, and Honors

Professor Ng is a leading scholar in synthetic biology, having won gold medals for seven consecutive years at the International Genetically Engineered Machine (iGEM) competition, and leading her team at NCKU to a world championship in 2019. Additionally, she has received several awards for her outstanding teaching and contributions to university social responsibility from NCKU (2020, 2021, 2022, 2023), the NCKU College of Engineering Research Excellence Award

(2021), the Outstanding Female Chemical Engineer Award from the Taiwanese Society of Chemical Engineers (2022), and the Outstanding Female Biochemical Engineer Award from the Taiwanese Society of Biotechnology and Biochemical Engineering (2023). She also received the Outstanding Research Award in Chemical Engineering from the National Science and Technology Council (2023).

Innovation and Breakthroughs in Research

Professor Ng has utilized CRISPR gene editing technology to modify metabolic pathways in microalgae and microbes, dedicated to developing carbon-neutral high-value chemicals through synthetic biology. There are three main innovations and breakthroughs: (1) Achieving a breakthrough in carbonic anhydrase using direct evolution techniques to accelerate the efficiency of carbon dioxide sequestration; (2) Developing smart cell factories that produce the precursor drug 5-aminolevulinic acid, achieving a production rate of 15 grams per liter in genetically modified *Escherichia coli,* ranking 5th globally in this field; (3) She is the first scholar to regulate genes in eukaryotic microalgae using CRISPRi and CRISPR, doubling the lipid content in *Chlamydomonas* and enhancing carbon fixation efficiency and protein production in *Chlorella*. Over the past three years, she has averaged 20 publications per year and was listed among the "Top 2% of Global Scientists" since 2020.

Significant Contributions to Chemical Engineering

In 2021, Professor Ng entered the top 40 of the FITI Startup Innovation Competition due to her team has established a smart cell "e-Touch" to produce drug for skin cancer therapy. Over the past nine years, she has led and participated in 13 projects funded by the Ministry of Science and Technology and four industry-academia projects, achieving carbon reduction and the production of high-value chemicals including cadaverine, used in bio-nylon, and 5-ALA for photodynamic therapy of skin cancer. Other products include putrescine, 4-aminobutyric acid,

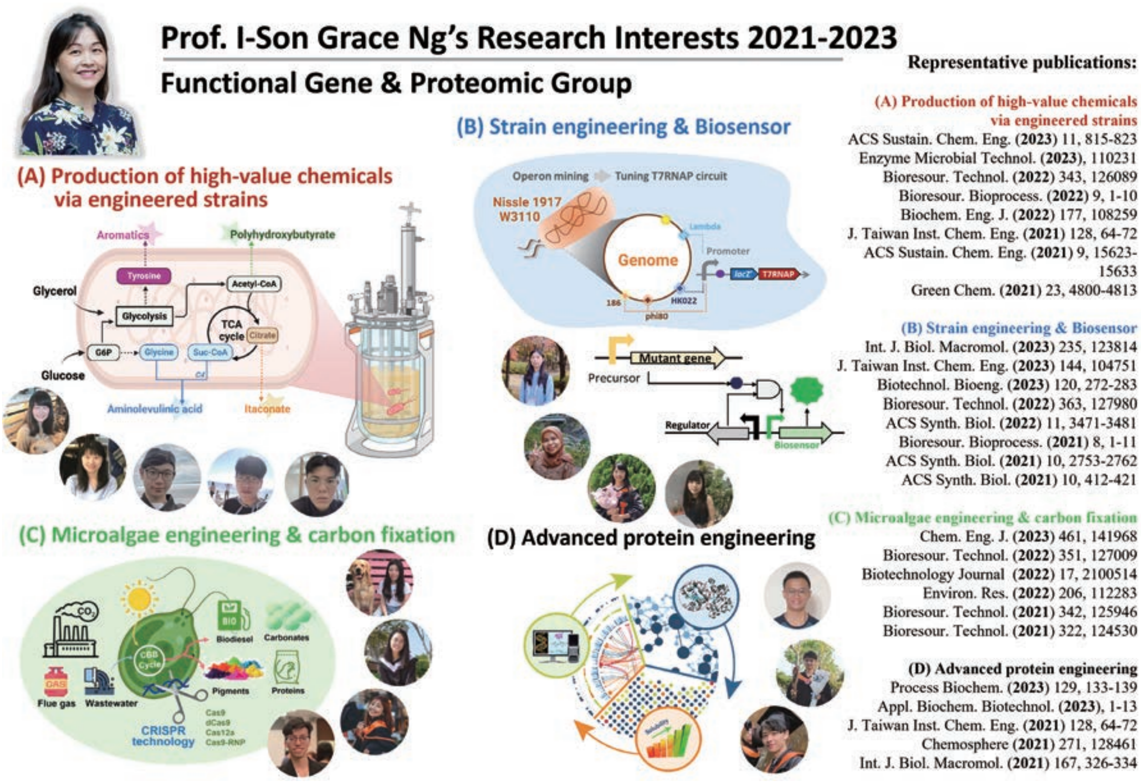
Meet 2016 Tang Prize Winner Dr. Feng Zhang in Broad Institute, Massachusetts Institute of Technology, USA in November, 2017.

p-coumaric acid and ferulic acid, all of which are crucial chemical raw materials, fully demonstrating her practical engineering capabilities.

A Global Team for Next-Generation

Professor Ng has mentored nine PhD students at NCKU, five of whom have graduated. Two have received the scholarship (千里馬計畫) from the National Science and Technology Council (MOST), and four have received the Outstanding Doctoral Dissertation Award from CTCI foundation (中技社). She has also mentored 18 master's graduates and guided over 20 undergraduate project students, six of whom have received undergraduate research grants from MOST or NSTC, reflecting her dedicated guidance and outstanding performance. She has also established an interdisciplinary course in synthetic biology at NCKU, leading students in interdisciplinary learning and implementing educational innovations. Currently, she has received the National Science Council's 2050 Net Zero Carbon Emission Project, leading her team to achieve new tasks in direct air carbon capture and utilization, which hopefully will reduce carbon dioxide from 400 ppm to 300 ppm in the air.

Professor Ng is more convinced that higher education research can have global influence! Every academic researcher should bravely face global crises and issues, not evade the academic responsibilities owed to the international community. Let us together fulfill our global academic responsibilities with "courage," "integrity," and "resolve"!



Professor I-Son Grace Ng leads Functional Genes and Proteomics Laboratory to solve the global issue using synthetic biology.

Advanced Power Electronics Technologies for Sustainable Energy Conversion and Applications

Tsorng-Juu Liang,
Distinguished Professor

Author Introduction

Biography: Dr. Tsorng-Juu Liang is currently a Distinguished Professor at National Cheng Kung University (NCKU), the President of the Taiwan Power Electronics Association, and the Editor-in-Chief of the IEEE JESTPE. He received the Outstanding Research Award from National Science and Technology Council in 2024, IEEE Fellow in 2016, and Outstanding Engineering Professor Award from the Chinese Institute of Engineers in 2015. Due to the efforts of Dr. Liang and the NCKU team in the field of power electronics, Lite-On Technology and Delta Electronics established the NCKU Joint Research and Development Centers at NCKU in 2023, and 2024, respectively. Dr. Liang has mentored over a hundred doctoral and master's students to date. He has published a total of 88 SCI journal papers, with over 13,000 citations on Google Scholar.

Power electronics is a branch of electrical engineering that deals with electrical power conversion, control, and conditioning using electronic power devices. Power electronics play a crucial role in various applications, including consumer electronics, industrial machinery, sustainable energy systems, transportation electrification, and grid resilience with power conditioning systems. The major research areas of Dr. Liang's laboratory include: high-frequency power converter technology using wide-bandgap semiconductor power switches, high step-up ratio DC-DC converters and control technologies for sustainable energy systems, power integrated circuits and converter controllers, battery management and balanced charging technology, and long-life LED driver. The details are as follows.

1. High-frequency power converter technology using wide-bandgap semiconductor power switches: Wide-bandgap compound semiconductor power switches, silicon carbide (SiC) and gallium nitride (GaN), have the characteristics of high-speed switching and low on-resistance. Thus, the converter size and weight are

reduced significantly by increasing the switching frequency.

The major researches are ultra-high frequency and high-performance resonant power converter, bidirectional DC-DC converters, and high-power grid-following inverters and grid-forming inverters for energy storage systems with high power-density.

2. High step-up ratio DC-DC converters and control technologies for sustainable energy systems: High step-up ratio DC-DC converters are crucial for renewable energy and electric vehicle applications. These converters boost low voltage sources to high voltage levels, enhancing the efficiency of downstream inverters or main power systems. Over 20 high-efficiency converters with step-up ratios, based on coupled inductor, switched capacitor, and switched inductor have been developed. In addition, three-port converters with high step-up ratio have been presented for sustainable energy with energy storage systems. A pioneer maximum power point tracking algorithm for photovoltaic system was developed. These researches have resulted in over 30 publications in top IEEE journals, with significant citations from leading research institutions worldwide with over 5,000 citations on Google Scholar, enhancing academic standing and influence in this field significantly.

3. Power integrated circuits and converter controllers: The performance of power converters highly relies on power integrated circuits and control algorithm. Quasi-resonant flyback controller, primary-side controllers for flyback, active-clamped flyback, and LLC resonant converter were developed. Moreover, the advanced controllers for asymmetric half-bridge flyback for USB-PD, current mode controlled resonant LLC converters, and dual-output resonant LLC converter are also presented. These technologies have been widely applied to

Lite-On-NCKU Joint Research and Development Center in July 2023

Delta-NCKU Joint Research and Development Center in January 2024

LCD TV power supplies, LED lighting, USB-PD, and household appliance chargers.

4. Battery management and balanced charging technology: Batteries are important components in energy storage and electric vehicle systems. In practical applications, many battery cells are connected in series and parallel to form a battery bank. It is critical to estimate battery capacity and lifespan accurately to avoid battery imbalance problem, which can lead to battery damage. Professor Liang's team has developed battery management and charging/discharging technologies, including: a. Through charging and discharging characteristic experiments combined with artificial intelligence analysis techniques, an accurate method for estimating the capacity and lifespan of lithium batteries has been developed. b. The battery charging circuit architectures with battery balancing circuits have been well developed.

5. Long life LED driver circuit research: With their high luminous efficacy and long lifespan, LEDs have become the primary light sources in many applications. Innovative research areas include AC-LED current limiting technology, multi-stage conduction AC-LED driving technology, capacitor-compensated LED driving technology, automatic switching technology for LED modules, and LED driving technology without electrolytic capacitors.

CubeSat Development and Application

Jyh-Ching Juang,
Distinguished Professor

Author Introduction

Jyh-Ching Juang

Distinguished Professor,
Department of Electrical
Engineering, NCKU

In recent years, the space has under a resurgent transformation due to the introduction of miniaturization in components, softwareization in functionality, and democratization in entities. In this new space era, the information and communication technology has played an essential role to realize remote sensing, communication, navigation, and science missions. Recent advances in artificial intelligence push this ever further. On the other hand, opportunities of access to space have become more abundant as the costs are being reduced. More than 80 counties have launched satellites and many more startups are devoted to space industry and commence. The trend is characterized in terms of S8 which stands for small, smart, swarm, standardization, software, service, security, and safety. Indeed, satellites are being built with small form factor and embedded intelligence. With a constellation of satellites, guaranteed level of service quality in temporal and spatial domains can be assured. This then setup a platform for the development of innovative technologies and services. Naturally, standardization further push for the business development. It is also noted that as the satellites are becoming nodes of connectivity, cybersecurity must be designed-in. Further, the proliferation of satellites in low-Earth orbits leads to issues of debris and collision, raising concerns on safety. In Taiwan, the Space Development Act has been in place and several space programs are underway for remote sensing and communication.

The CubeSat standard is considered as an important driver for the new space as the standard lowers the entry bar and encourages many college students, young talents, and start-ups to take part with innovations and enthusiasms. The Space Laboratory of the National Cheng Kung University is dedicated to the development and operation of CubeSats. Ever since 2014, the Laboratory has launched seven CubeSats to verify and validate enabling techniques and services as depicted in Figure 1. In the past two and half years, the Laboratory has launched five CubeSats, including IRIS-A, IRIS-C, IRIS-C2, Lilium-1, and IRIS-F1 all accomplishing their respective missions successfully. This amazing accomplishment of five satellites in space has made NCKU unique in the world as very few universities would operate so many satellites at a time.

Even though CubeSats are small in size, the development has to conducted

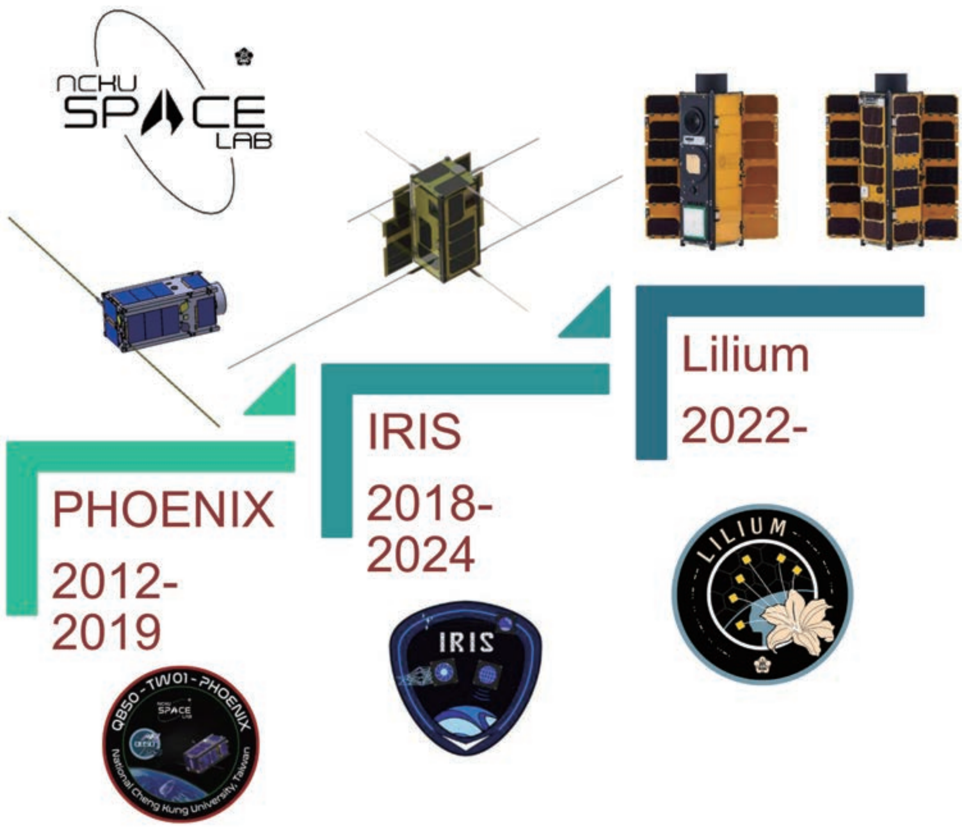


Figure 1 CubeSat development at the Space Laboratory, NCKU

through a rigorous systems engineering process with different phases of reviews. Typically, the space system goes through the analysis, design, manufacturing, assembly, integration, and test stages before it is launched. Afterword, the satellite is operated in space for a period of time to verify technology and perform mission. The education value of developing CubeSat at a University is to provide comprehensive systems engineering training and hands-on experiences. Several generations of NCKU students have been trained and contributed to the promotion of open-source CubeSat design, space startups, and advancement of space infrastructure. Figures 2 and 3 illustrate the developments of the PHOENIX and IRIS-A CubeSats, respectively. PHOENIX is a 2kg class CubeSat that was launched in 2027 and de-orbited in 2019. The PHOENIX CubeSat is a part of the European QB50 program and the successful operation of the satellite for two years has rendered a significant amount of satellite bus and payload data for the research of lower thermosphere. The satellite project also regarded as pivotal in science accomplishment, engineering education, and international collaborations. As noted from Figure 2, it took five years for the development of the PHOENIX before its launch. Thereafter, the Space Laboratory based on the heritage engaged in the development of IRIS series CubeSats. IRIS standing for Intelligent Remote sensing and Internet Satellite aims to provide a space platform for the promotion of artificial intelligence and space connectivity. The

Figure 2 Development of the NCKU PHOENIX CubeSat

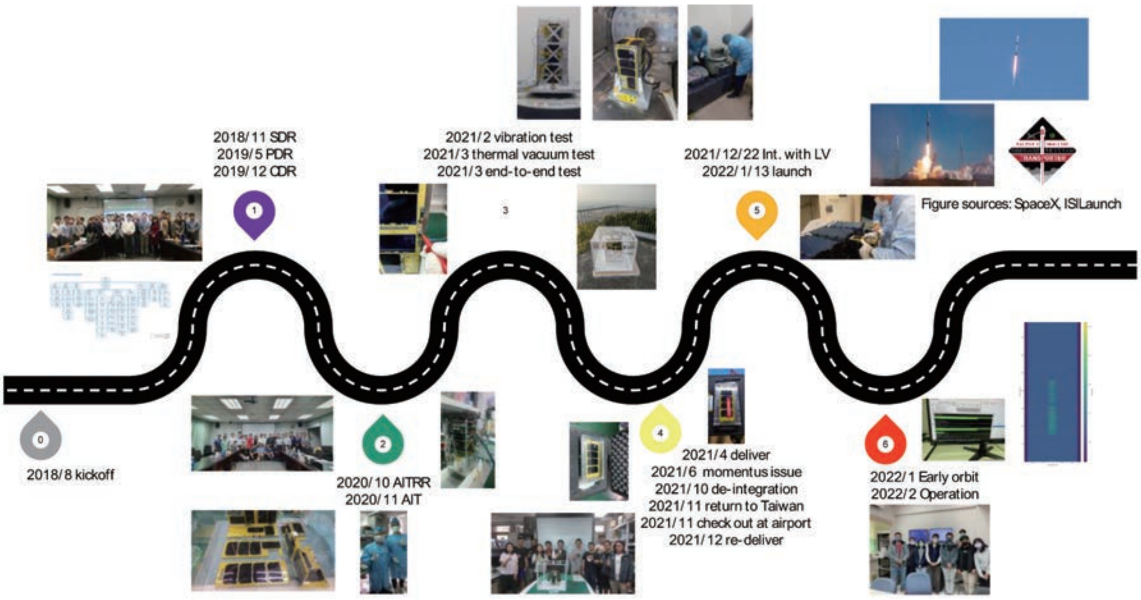


Figure 3 Development of the NCKU IRIS-A

IRIS-A was successfully launched in January 2022 after three years of development as depicted in Figure 3. The 2-kg IRIS-A has verified attitude control, photo taking, GPS receiver, and space internet technologies in space. Afterwards, the IRIS-C and IRIS-C2 CubeSats were launched in April and November 2023, respectively, for the purpose of in-space verification and validation of bus components and technologies. The two satellites successfully provide in-orbit data. The successful deployment of the 3-kg IRIS-C/C2 further demonstrated that the Space Laboratory has materialized a stable platform and infrastructure for CubeSats. This then leads to the development and launch of the IRIS-F1 in March 2024. The Lilium-1 is a CubeSat that is supported by the

(a)

(b)

Figure 4 Picture taken by NCKU Lilium-1 CubeSat

National Science and Technology Council (NSTC). The missions are to verify high-speed (S-band) communication, space internet, and optical payload. Ever since its launch in December, 2023, the Lilium-1 has been operating almost flawlessly. Figures 4(a) and 4(b) depict two pictures that was taken by the Lilium-1. The southern part of Taiwan is clearly visualized.

Looking forward, the Space Laboratory plans to launch two CubeSats, Lilium-2 and Lilium-3, in 2025. These two CubeSats will test and verify several key techniques that are applicable to CubeSats and microsatellites. More precisely, the Ku-band communication payload will be developed and tested. This aims to provide an end-to-end testbed for space-ground Ku-band communication. The design in the satellite part is noted by using an antenna array with software-defined transceiver to perform combined satellite motion and adaptive beam forming for link establishment and maintenance. A smart remote sensing payload will also be developed to realize high-resolution image acquisition and edge AI processing. This remote sensing payload is also noted for its feature of indigenous design including a reflective lens, CMOS sensor, and deep learning algorithms. The Lilium-3 will perform in-orbit tests of electric propulsion and deployment mechanism experiments. It is anticipated that the development of these key technologies together with the mature CubeSat platform technologies can be integrated to enhance the overall system level technology readiness level. The Lilium project is a multi-university project in which NCKU serves as the principal investigator with contributions from National Taiwan University, National Taiwan University of Science and Technology, and Tamkang University. In the future, a further consolidation of resources will be achieved by establishing a university-level CubeSat Research Center for the advance of innovative space technologies, incubation of talents, collaborations with industry, and promotion for international cooperations.

Enhancing Robotic Teleoperation with Human Motion-Based Interfaces and Mixed Reality Environments

Yen-Chen Liu,
Professor

Author Introduction

Professor Yen-Chen Liu is a faculty member in the Department of Mechanical Engineering at National Cheng Kung University (NCKU) in Tainan, Taiwan. His research interests include the control of networked robotic systems, bilateral teleoperation, multi-robot systems, mobile robot networks, and human-robot interaction. As a leading scholar in the control theory of cyber-physical robots, his outstanding achievements significantly contribute to the theoretical development of robot control in Taiwan, promoting future innovative research and enhancing the field's international academic status and influence.

In recent years, Professor Liu has focused on resilient control for cyber-physical robot systems, particularly in intuitive human-robot interaction applications. By combining innovative concepts with rigorous theoretical analysis and experimental verification, he has developed numerous unique and valuable solutions and published many influential and forward-looking research works, solidifying his position as a leading researcher in this field in Taiwan.

As the demand for robotic applications in unmanned facilities grows, robot autonomy has become a significant area of research. However, robotic intelligence often struggles in highly unstructured or complex environments and lacks the flexibility for real-time task assignment and redesign.

Teleoperation, where a human operator controls a robot remotely through an interface, presents a promising solution for real-time robotic control. This method ensures the operator's safety in hazardous environments, including in-space operations. Despite its potential, traditional teleoperation interfaces, such as joysticks, keyboards, and low-degree-of-freedom (DoF) haptic devices, are limited. When teleoperating a high-DoF remote robot, dimension mismatches between the local teleoperation interface and the remote robot, or coupling between different directions in a low-DoF local robot, can create cumbersome and non-intuitive experiences for the human operator. This reduces teleoperation performance and increases task completion time. Moreover, most teleoperation systems provide only 2D visual feedback or assume the operator and the robot are in proximity with full-vision surveillance.

This research introduces a human motion-based teleoperation interface. Five Inertial Measurement Units (IMUs) are placed on the operator's chest, right shoulder, right upper arm, right wrist, and right palm to capture the configuration of the operator's right hand, as shown in Fig. 1. By using the human arm forward kinematics model, the right-hand palm's pose, including position and orientation, is used to control the remote robot's end-effector. Unlike optical-based and visual-based motion capture systems, this wearable motion capture device allows the operator to move freely without being restricted to a specific area, enhancing versatility for various applications.

While most teleoperation systems use manipulators as remote robots, mobile manipulators are increasingly appealing for a wide range of applications. A mobile manipulator, which integrates a manipulator with a mobile platform, combines the dexterity and high manipulability of a manipulator with the locomotion capability and unrestricted workspace of a mobile base. In this research, a mobile manipulator is used as the remote robot to maximize adaptability across different applications and scenarios.

Two operating modes are provided for the teleoperation architecture: Manipulation mode and Locomotion mode. In Manipulation mode, a torque-based controller is designed for the manipulator to track the operator's motion. Radial basis function neural networks (RBFNN) are employed to compensate for dynamic uncertainties. Unlike kinematic-based controllers, such as position control, the torque-based controller can handle force information when interacting with the environment, providing a safer teleoperation experience. In Locomotion mode, a velocity-based control strategy allows the operator to control the mobile platform's linear and angular velocity. The linear velocity is managed by monitoring the operator's hand position in vertical movement—the higher the position, the greater the commanded linear velocity. The angular velocity, on the other hand, is controlled by the operator's horizontal movement.

Given the challenge of teleoperating a mobile manipulator, providing comprehensive visual feedback is impractical due to the mobile manipulator's locomotion capability. Full-vision feedback in unrestricted or unexplored areas is uneconomical and difficult to achieve. However, advancements in VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality) technologies offer opportunities to enhance user experience and immersion. This research introduces a real-time MR-based virtual environment

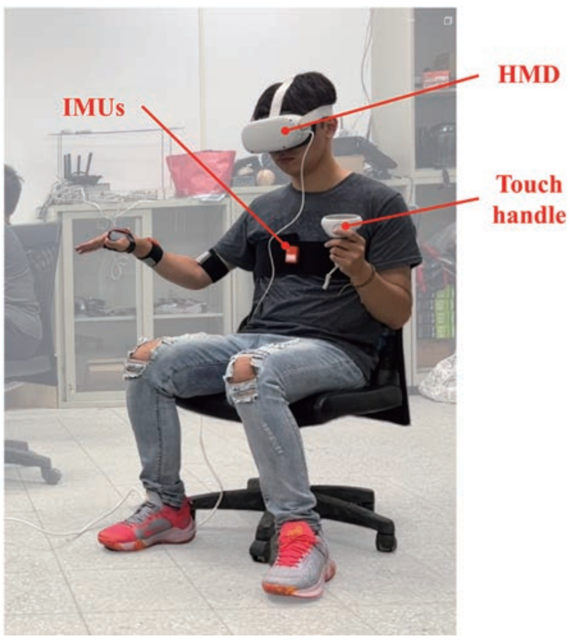


Fig. 1. Human operator wearing an HMD on the head, with IMUs on the right hand, and holding a Touch handle in the left hand.

to provide operator feedback. The remote environment is recreated in Unity3D using SLAM (Simultaneous Localization and Mapping) techniques with a Lidar sensor on the mobile platform, while real-time 3D/2D visual information is provided by an RGBD camera on the manipulator. A digital twin of the remote mobile manipulator is visualized using real-time data from the manipulator and odometry data from the mobile platform, aiding the operator's interaction with the environment. The virtual environment is presented through a head-mounted display (HMD) device, providing an immersive operating experience, as depicted in Fig. 1. The Touch handle from the Meta Quest VR set allows users to switch between Manipulation and Locomotion modes and offers additional functions, such as viewing angle adjustment and gripper control.

To validate the proposed teleoperation scheme, several tasks were designed to evaluate control performance. The operator is asked to guide the remote mobile manipulator to another room by opening a door (see Figs. 2(a) and 2(b)). After that, the operator opens a box on a table and grasps a target object inside the box (Fig. 2(c)), then returns to the first room to place the object in an assigned spot, as shown in Fig. 2(d). These tasks encompass various common operations, such as door-opening, pick-and-place tasks in Manipulation mode, and exploring open spaces and traversing narrow passages in Locomotion mode. Fig. 2(e) presents the virtual environment created in Unity3D during the tasks. Several novice participants were asked to complete the tasks for five runs. Most participants successfully completed the tasks on their first trial, even without prior experience in teleoperation control and MR environments. The recorded duration times showed that most participants exhibited standard deviations 20% lower than the mean duration, highlighting the intuitiveness of the teleoperation interface and the minimal need for extensive training.

With the implementation of the proposed teleoperation architecture, operators can intuitively control the remote mobile manipulator using hand position and orientation, significantly reducing the learning curve for novice users. Additionally, the immersive MR environment allows operators to observe and interact with the remote environment through comprehensive 3D visualization. This enhanced user experience not only improves task efficiency but also minimizes the need for extensive training, making the system more accessible and effective for various applications.


(a) (b) (c) (d) (e)

Fig. 2. Tasks designed to evaluate the performance of the teleoperation architecture

Ensuring Coastal Safety and Sustainable Development

Shih-Chun Hsiao,
Distinguished Professor

Author Introduction

Dr. Shih-Chun Hsiao received his Ph.D. degree from the School of Civil and Environmental Engineering, Cornell University, New York, USA, in 2000. He started the position of assistant professor of Civil Engineering at National Taipei University of Technology in 2000, and then moved to Taiwan Ocean University in 2005 and National Cheng-Kung University in 2006. Currently, he serves as a Professor at the Department of Hydraulic and Ocean Engineering, National Cheng-Kung University, Taiwan. His research interests are directed towards a better understanding of coastal processes such as wave evolution from generation to the shoreline, hydrodynamic interactions with coastal structures, and surf-zone hydrodynamics. Investigations combine numerical modeling with well-controlled and high-resolution experiments. He also served as an editorial board member of international journals including Coastal Engineering, Applied Ocean Research and Coastal Engineering Journal.

In recent years, my research has focused on marine and coastal disaster prevention and mitigation, divided into two areas: fundamental research and applied research:

In fundamental research, I focus on "wave-structure interaction" and "climate change impact assessment". The interaction between waves and structures is crucial in coastal disaster prevention engineering. I have long been dedicated to this research field through numerical simulations, physical model experiments and field investigation. Research topics include long wave interaction with coastal structures (Hsiao & Lin, 2010; Wu & Hsiao, 2013) and wave energy attenuation by vegetation (Hsiao & Hsiao, 2022; Hsiao et al., 2023). In addition, to gain a practical understanding of the impact of tsunami events, I have supervised PhD students in conducting field investigations of the two tsunami events that occurred in Indonesia in 2018 (Widiyanto et al., 2019; Widiyanto et al., 2020). These research outcomes not only help to understand the characteristics of flow fields but also provide structural design information that can effectively resist wave attacks, which can be used in practical engineering designs, thereby improving engineering protection effectiveness.

In terms of climate change impact assessment, my research team has developed compound disaster coupling simulation techniques for storm surges, rainfall, and topographic changes based on the core technology of coastal resilience construction. Furthermore, by combining climate change scenario analysis with compound disaster simulation techniques, we have proposed a research framework to assess the coastal impact due to climate change. The research framework is shown in Fig. 1 and typical simulated flood extents for Yunlin and Chiayi are displayed in Fig. 2 (Hsiao et al., 2021). It is clearly seen that the flood areas are concentrated in the lower part of the coastal region along the coastline of Yunlin and Chiayi. The flood extent in F_t is slightly higher than that in P_t without compound effect. With compound effect, the flood extent in F_{t+r} becomes much larger than that in P_t, especially around the riverside areas where river overflow occurs due to the conjugation of upstream pluvial water and downstream surge water. The above-mentioned methodology breaks through the limitations of previous analyses that focused solely on single disasters, enabling a more reasonable assessment of coastal impacts and enhancing the nation's coastal resilience research capabilities. We have also proposed innovative coastal topography simulation methods. Particularly, we advanced an integrated framework for the analysis of decadal morphological changes in barrier islands. When applied to Taiwan's Waisanding Barrier Island, this refined methodology proved both precise and effective. More detailed results can be found in Lu et al. (2024).

In applied research, I focus on the "development of coastal disaster prevention technology", with an emphasis on breakthroughs and contributions in "intelligent coastal disaster prevention". Taiwan's seawalls often face the risk of wave overtopping, and the runup height is an important indicator for assessing wave

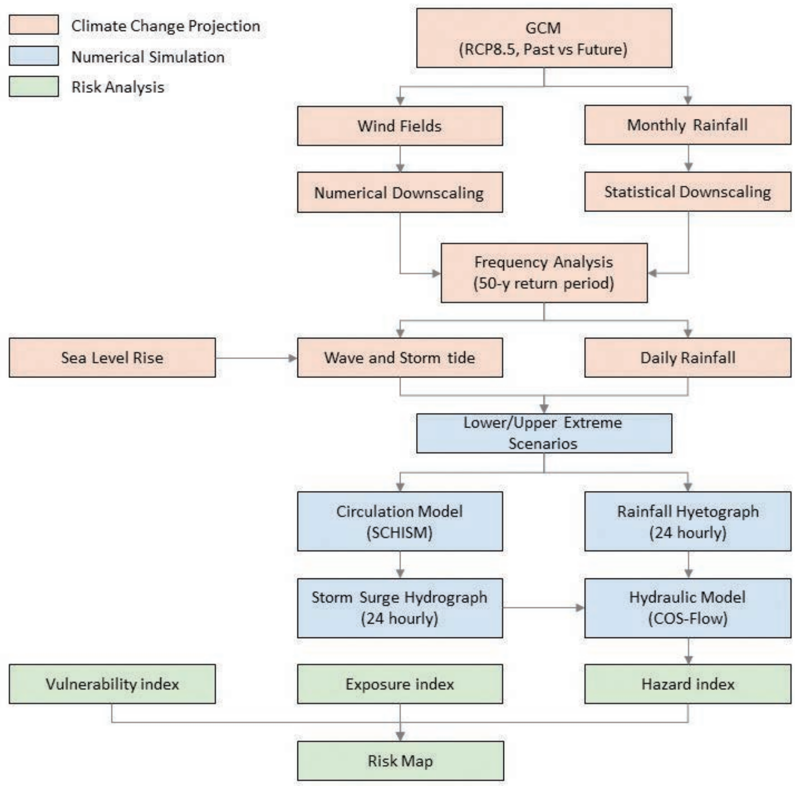


Fig. 1. Framework for compound flood risk analysis under climate change.

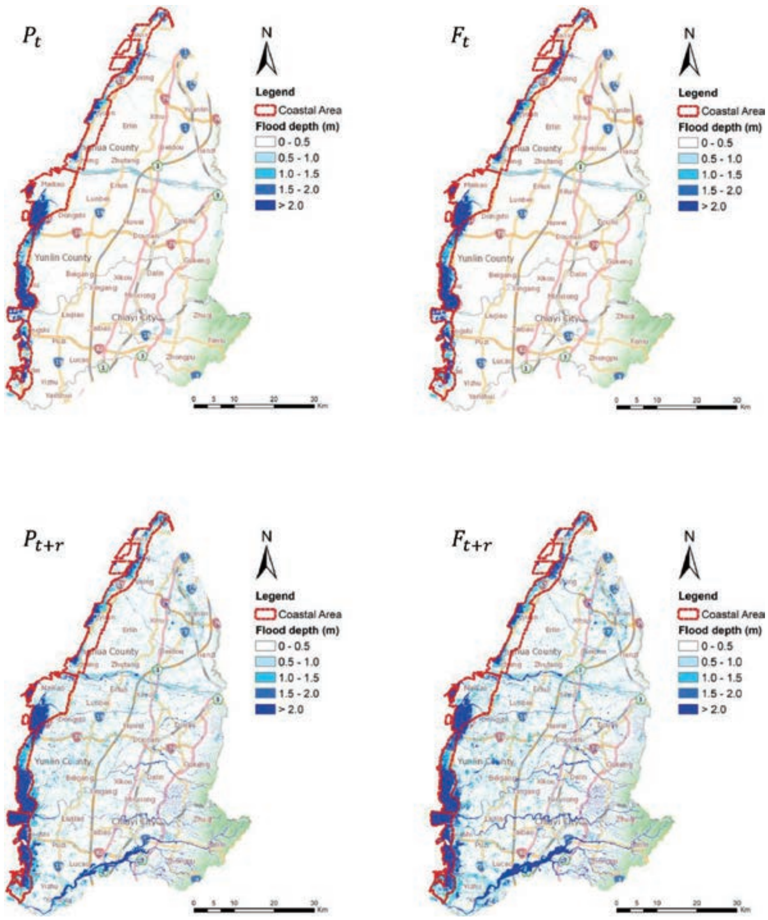


Fig. 2. Simulated flood extents for different scenarios (P_t: past period without compound effect; F_t: future period without compound effect; P_{t+r}: past period with compound effect; F_{t+r}: future period with compound effect)

overtopping conditions. However, existing methods are only suitable for section monitoring and early warning, which is insufficient for Taiwan's coastline exceeding one thousand kilometers. Therefore, our team, based on the concept of "intelligent coastal disaster prevention", has combined numerical experiments, forecasting, Internet of Things (IoT) observations, image recognition, and machine learning (ML) to establish an AI-based intelligent coastal run-up early warning and real-time image monitoring system. This system helps relevant agencies respond in advance to enhance disaster prevention effectiveness. Additionally, by continuously collecting run-up data, we feed back to train the forecasting model, improving the system's accuracy. In Fig. 3, the current machine learning modeled results show good agreement with the field observed data. It is expected that the accuracy of the model can be further improved by incorporating sensor and image interpretation observation data in the future.

To this end, since 2021, our team have been collaborating with public sector to construct a localized intelligent micro-scale surge sensing system. This system aims to meet the needs for long-term data collection, real-time flood monitoring, and widespread deployment in the future. On the other hand, to enhance the wave forecasting capabilities of marine weather prediction models, we are continuously developing typhoon wave calculation techniques suitable for domestic use, to improve typhoon event simulation technology. The research employs hybrid wind field techniques, combining reanalysis wind field and parametric wind field data, to generate more reliable typhoon wind fields for typhoon wave hindcasting, thereby improving the accuracy of wave field hindcasting. By calibrating and testing the parameters related to the hybrid wind field, we propose suitable parameter values for domestic use and study the appropriate methods for hybrid wind field application.

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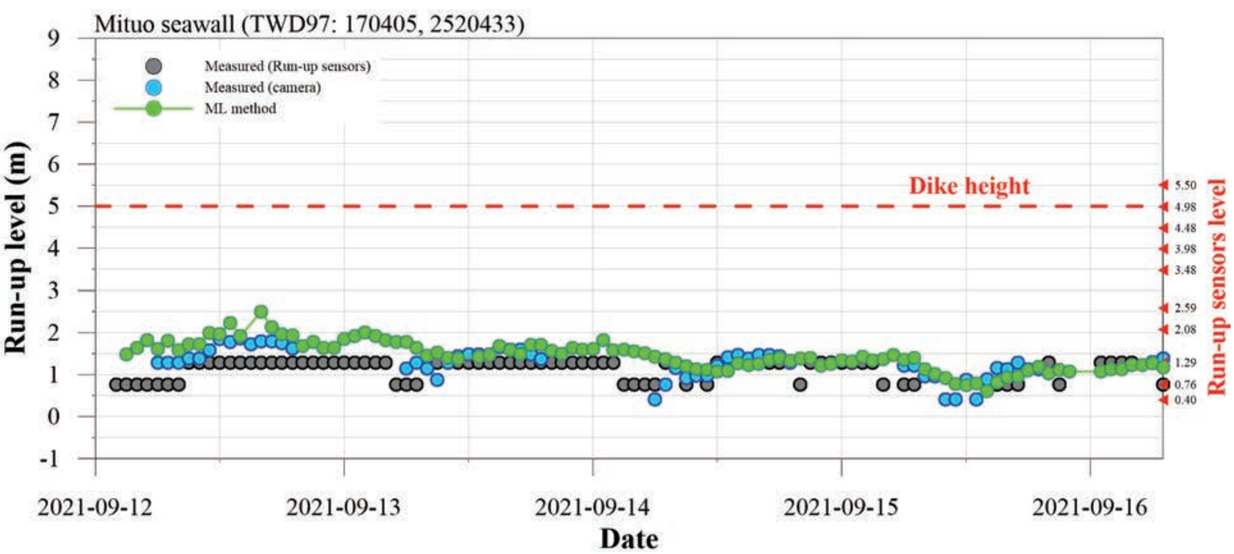

Fig.3. Comparison of ML-modeled and measured hourly maximum wave runup heights on the Mituo seawall during the typhoon Chanthu in 2021

2024 Global Views University Social Responsibility Awards

The Project to Improve the Quality of Lunches for Rural Elementary and Secondary School Students

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Revolutionizing Taiwan's Passive Component Sector: Innovations, Partnerships, and Talent Development

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Conservation and Practical Actions, and Educational Promotion of Marine Wildlife in Maritime Nations

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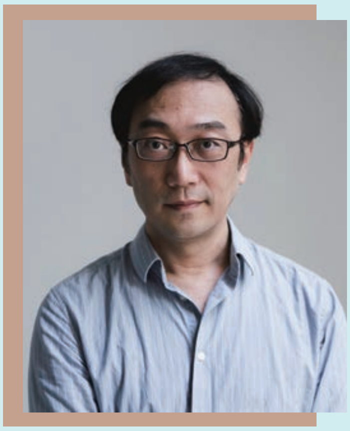
Tree Finder – The Giant Tree Map Project

The Project to Improve the Quality of Lunches for Rural Elementary and Secondary School Students



Li-Wen Sung,
Associate Professor

Team Introduction

This project, commissioned by the Ministry of Education's K-12 Education Administration, is executed by the Research Center for Humanities and Social Sciences at National Cheng Kung University. The prominent team members include Associate Professor Li-Wen Sung from the Department of Architecture, Professor Chung-I Lin from the Center for General Education (currently serving as the President of Huafan University), and researchers Jia-Hao He, Pei-Hong Lai, Shao-Wei Wang, Xin-Hong Pan, Wei-Ting Tang, and Kan-Ru Chen from the Research Center for Humanities and Social Sciences. The primary tasks focus on addressing the supply and quality issues of food ingredients for nutritious lunches in rural elementary and secondary schools. Additionally, the project aims to establish an ideal model of a central kitchen on campus to develop food and agricultural education.

Since the central government promulgated the policy in 1982, each county and city has independently managed elementary and secondary school lunches for 40 years. However, with the widening gap between urban and rural areas, rural schools have faced increasing difficulties in their supply chains. Our project team has continuously focused on and researched the issue of school lunches in rural areas. Collaborating with the Ministry of Education's K-12 Education Administration, the Ministry of Agriculture's Agriculture and Food Agency, and education bureaus from various counties and cities nationwide, we have promoted a series of innovative school lunch programs. We have also submitted two primary policy suggestions to the K-12 Education Administration: establishing central kitchens and joint procurement of food ingredients to achieve reasonable economies of scale in lunch supply. With policy support from the competent authorities, our team has taken on the responsibility of frontline implementation, aiming to ensure that rural schoolchildren have enough to eat and eat well. Therefore, in addition to integrating food ingredient procurement across schools to improve food quality, the establishment of central kitchens must also focus on promoting food, agricultural, and dietary education, and this process involves integrating numerous stakeholders. The main achievements over the past three years are twofold: 1. We have completed constructing or expanding central kitchens in 123 rural schools, serving over 600 satellite schools and benefiting nearly 100,000 students. 2. We have coordinated the development of consensus among schools to promote joint school lunch menus. This project has organized various case-sharing sessions and consensus camps, with nearly 800 participants, including relevant personnel and nutritionists from counties and cities, attending these events in 2023. This indirectly facilitated forming more school groups for joint procurement, thereby improving the quality of rural school lunches.

The implementation of this project can be briefly described as follows:

1. Demonstration Cases for Optimizing the School Lunch Supply Chain in Rural Areas: Centering on the needs of rural schools, we continuously improve the lunch supply chain through cross-departmental communication and coordination, accompanying schools and suppliers. We have created numerous exemplary cases through effective communication and coordination with local governments and relevant stakeholders.

2. Proposing Policy Drafts to Assist the Government in Structurally Improving the National School Lunch Supply Chain in Rural Areas: The project team proposed a policy plan centered on joint procurement, supplemented by related subsidies for transportation and manpower. Following the Executive Yuan's promulgation of the "Promotion The Central Kitchens Project for Rural Schools," we assisted local governments in establishing central kitchens and joint procurement school groups. We discussed appropriate and effective implementation methods with each county and city, balancing policy implementation with local relationship management.

3. Introduction and Empowerment of Nutritionists in Rural Schools: The project team continues to deepen cooperation

偏鄉學校營養師菜單表揚活動__ Rural school nutritionist and school menu commendation ceremony

偏鄉學校聯合菜單共識營__ Rural schools joint lunch menu consensus camp with school lunch workers, organizing ten training sessions and seven workshops in 2023 alone, with 1,056 participants. The workshops introduced design thinking to help nutritionists share their lunch management experiences with new nutritionists in rural schools through hands-on practice and exchanges.

4. Promoting Plans to Build and Expand Central Kitchens in Rural Schools: The project team integrates scholars and professionals in architectural design, facilities, and food safety to form a support group. This group assists local governments and rural schools through early planning, bidding, design, contracting, construction, acceptance, and project closure, ensuring that the completion of new kitchens enhances the quality of school lunches. The main implementation strategies are twofold:

Strategy 1: Treat the lunch kitchen as a space to develop "food education" and "dietary education," making it an important activity area on campus. During their time at school, a nutritious lunch is vital for students. Generally speaking, kitchens have not been given much attention. This project aims to promote the construction of central kitchens, benefiting more children. In addition to improving food quality, the project also showcases the cooking process as a method to encourage dietary education. Through the advanced kitchen concept of this project, the goal is to enhance the layout and environment and upgrade hardware facilities. Whether it is new construction or expansion, to improve the environmental quality, we aim to streamline workflow and steps by updating equipment or placing it in better locations, thus reducing unnecessary labor costs and minimizing the risk of work-related injuries.

Strategy 2: The space of the lunch kitchen should be a friendly environment that demonstrates quality work practices while

left to right: Shao-Wei Wang, Xin-Hong Pan, Li-Wen Sung, Jia-Hao He, Wei-Ting Tang, and Pei-Hong Lai incorporating the principles of HACCP, advocating food safety concepts. The design concept and kitchen layout of this project focused on optimizing work flow. From the entrance, receiving, and inspection areas to the pre-operational disinfection zone, the planning of each area follows proper food safety and hygiene procedures and ensures the smooth flow of processes through the arrangement of equipment and personnel pathways. These improvements aim to enhance the working conditions for chefs in new kitchens.

Schools in rural areas are often places that general food ingredient suppliers are unwilling to serve. Our years of investigation have found that if schools and suppliers can strengthen communication and coordination based on procurement contracts, it can benefit both parties the most. Therefore, the project team's execution strategy adheres to value co-creation for school lunches, focusing on interactive participation with stakeholders rather than unilateral output. By integrating resources across disciplines, we collectively create value. Following the establishment of the "School Lunch Section" by the K-12 Education Administration in 2023, our team also assisted local governments in setting up school lunch advisory teams to continuously improve lunch quality and maximize the educational significance of school lunches. Our project is the only team in Taiwan dedicated to school lunches across various counties and cities nationwide. The central government supports our policy suggestions. As these policies are promoted, public attention to school lunches has increased, facilitating the Legislative Yuan's efforts to promote the enactment of relevant specialized laws.

桃園市新坡國小__ Central Kitchen, Hsin-Po Elementary School, Taoyuan City

Chung-I Lin, President of Huafan University

Revolutionizing Taiwan's Passive Component Sector: Innovations, Partnerships, and Talent Development

Team Introduction:

Wen-Hsi Lee

Distinguished Professor, Department of Electrical Engineering, NCKU

Hsing-I Hsiang

Professor, Department of Resources Engineering, NCKU

Shih-Kang Lin

Distinguished Professor, Department of Materials Science and Engineering, NCKU

Yu-Ze Chen

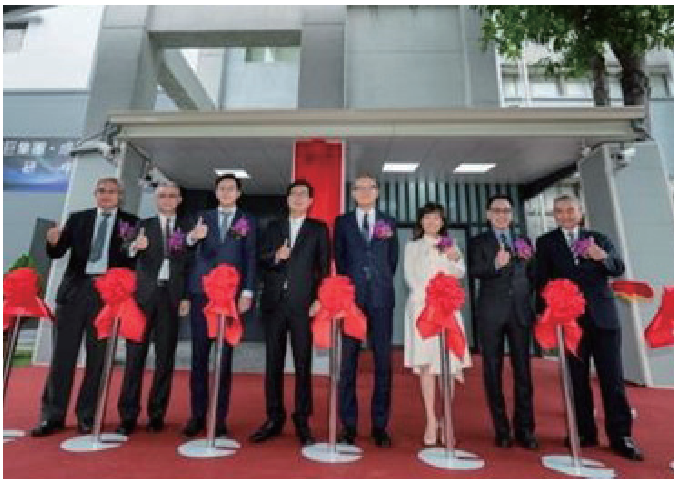
Assistant Professor, Department of Materials Science and Engineering, NCKU

—— Wen-Hsi Lee,
Distinguished Professor

The passive component industry in Taiwan is a significant player in the global electronics supply chain. Passive components are essential elements in electronic circuits, including resistors, capacitors, and inductors, among others. Despite their small size and simple construction, these components are indispensable for various electronic devices, ranging from smartphones and computers to automotive systems and industrial machinery.

However, despite its crucial role, the passive component industry in Taiwan faces several key challenges, including a lack of industry competitiveness, a shortage of technical talent, insufficient product innovation, and weaknesses in supply chains. To address these challenges, Professor Wen-Hsi Lee builds a strong team including of Professor Hsing-I Hsiang, Professor Shih-Kang Lin, and Professor Yu-Ze Chen to initiate a project funded by the National Science and Technology Council's AIR Center program. This initiative embodies a forward-looking collaboration between academia and industry, with a focus on leveraging aluminum, one of the Earth's most abundant metals, to drive innovation in four crucial areas of passive component technology:

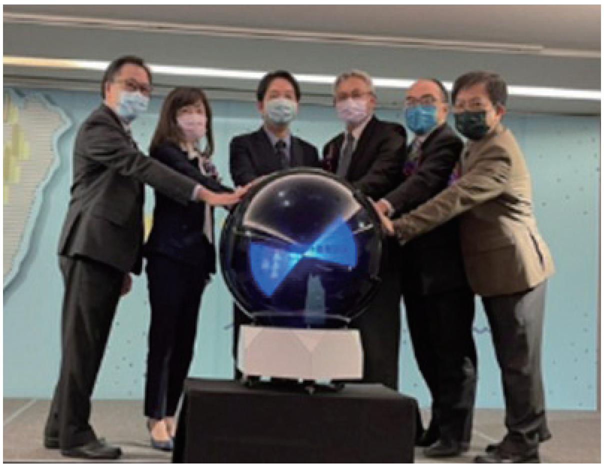
1. **Circular Economy:** Developing environmentally friendly additive copper wire manufacturing processes for radar antennas used in soft-board cars.
2. **Sub-metalized High-Reliability Chip Resistors for Automotive Use**: Enhancing reliability in automotive chip resistors through sub-metalization techniques.
3. **Low-Stress Copper-Free Terminal Electrode Multilayer Ceramic Capacitors for Automotive Use**: Developing capacitors with low stress and copper-free terminals for automotive applications.
4. **Sub-metal Material Technology for High-Temperature Sintering in Air**: Innovating sub-metal materials that can undergo high-temperature sintering in the air.



In the picture above, distinguished guests and the NCKU team are taking a group photo in front of the Yageo-NCKU Joint Research Center at the Nanzi Base in Kaohsiung.

The project plays a significant role in establishing joint research centers, as demonstrated by the collaboration between NCKU and Yageo Corporation, the world's third-largest and Taiwan's largest passive component manufacturer. This partnership fosters efficient collaboration and long-term research endeavors. Supported by an annual investment exceeding NT$30 million from industry, academia, and government, this initiative pioneers a dual-base model for joint research centers. It aims to facilitate effective collaboration between academia and industry while promoting continuous, long-term research and innovation in passive component technology and products. Through initiatives such as internships, scholarships, and specialized courses, the project endeavors to equip students with the essential skills and knowledge required for the industry. Prof. Lee has also launched the "Passive Component Industry Doctoral Program" to attract and nurture talent through diverse channels to solve the issue of shortage of technical talent.

In alignment with NCKU's dedication to social responsibility and fostering innovative academia-industry collaboration, Prof. Lee has played a pivotal role in uniting 70 upstream and downstream companies to establish the Taiwan Passive Component Industry Association. This association aims to fortify the entire ecosystem of the industry's supply chain and enhance global competitiveness. Prof. Lee has spearheaded the organization of international forums, a vital aspect of the project's efforts to facilitate technology exchange and align with global standards.



In the picture above, the Taiwan Passive Component Industry Association(TPCIA) held its inaugural meeting and invited Vice President Ching-Te Lai, National Cheng Kung University President Huey-Jen Su, Metal Industries Research & Development Centre Deputy Executive Director Chih-Lung Lin, Taiwan Passive Component Industry Association Founder Professor Wen-His Lee, and several distinguished guests to attend.

The project involves significant fundraising, the establishment of three new startups, and focuses on innovation in capacitor and resistor materials, as well as environmentally sustainable processes for copper wire manufacturing. The goal is to generate significant patent technology transfers, with an estimated industry output value of NT$15 billion, thereby strengthening Taiwan's position in the upstream advanced materials supply chain for the electronics industry and enhancing global competitiveness.

To achieve substantial energy savings, carbon reduction, and enhance international competitiveness and sustainable development in Taiwan's passive component industry, the initiative aims to transition towards a net-zero carbon emissions vision. This involves establishing a Taiwan Passive Component Industry-Academia Alliance focused on smart, low-carbon automotive passive components, materials, and equipment technology development. Integration of AI digital technology is emphasized for industry transformation, with a focus on achieving global leadership in passive component manufacturing.

The planning of publication of Taiwan's first passive component industry white paper aims to identify the current status, challenges, and opportunities in the industry, as well as forward-looking policies focusing on digital AI technology and sustainable zero-emission technology. The goal is to utilize digital technology to improve product quality and stability, penetrate the blue ocean automotive market, and develop clean energy, low-carbon processes, and circular material technology to realize a green and circular passive component industry ecosystem, positioning Taiwan as a global leader in the field by 2030.

In conclusion, the project's multifaceted strategy not only confronts the industry's challenges head-on but also lays the groundwork for sustained success and global leadership in Taiwan's passive component sector. By fostering innovation, fostering collaboration, and nurturing talent, it not only addresses immediate obstacles but also sets the stage for long-term growth and resilience. Through these concerted efforts, Taiwan's passive component industry is poised to emerge stronger, more competitive, and better equipped to navigate the ever-evolving landscape of the global electronics market.

Conservation and Practical Actions, and Educational Promotion of Marine Wildlife in Maritime Nations

Hao-Ven Wang,
Professor

Author Introduction

Dr. Hao-Ven Wang is currently as a professor in the Department of Life Sciences at NCKU. Since 2016, he also served as the Director of the Marine Biology and Cetacean Research Center at NCKU (NCKU MB&CRC). Over the past eight years, Professor Wang has led and also worked together with all volunteers and colleagues at the NCKU MB&CRC in assisting with over 270 stranded cetaceans, of which approximately 60 were live stranded individuals. Among these stranded individuals, 7 of them were processed as the "on site releasing" after checking the physical status were suitable for releasing together with the marine mammal veterinarian, and an additional 4 individuals underwent comprehensive medical care, rehabilitation, and assessment at the Cetacean Rescue Station at Sicao, Tainan before being successfully released. Professor Wang led the NCKU MB&CRC to receive accolades and honors in both the "Group" and "Individual" categories of the inaugural Ocean Conservation Contribution Model Award presented by the Ocean Affairs Council in 2023.

The very first time of the faculty and students at National Cheng Kung University participated and assisted for the stranded cetacean rescue operations can be traced back to late spring of 1993. In April and May of 1993, residents along the coasts of Tainan County and Tainan City discovered death stranded dolphins respectively (the first was one bottlenose dolphin (*Tursiops truncates*, 瓶鼻海豚). The second was one Pantropical spotted dolphin (*Stenella attenuate*, 熱帶斑海豚). Professor Chien-Ping Wang from the Department of Biology at NCKU, upon receiving the commission from local government authorities, promptly drove to the coast. By using a small sedan, the dolphin carcass was transported to the building of Department of Biology at NCKU, where the cetacean necropsy procedures commenced. Coincidentally, Hao-Ven Wang was exactly undergraduate student of the Department of Biology at NCKU at the time, and he also participated in several earlier cetacean necropsy operations.

Since 2000, the NCKU Cetacean team

A bottlenose dolphin was released after proper medical cares and rehabiliration in rescue stattion in 2022.

started attempting for the live stranding cetacean rescues missions. In January 2004, a carcass of an adult male sperm whale (*Physeter macrocephalus*, 抹香鯨), estimated to have been dead for several days and measuring over 17 meters in length, was discovered on the coast of Taixi, Yunlin County. During the process of salvaging, hoisting, and transporting the carcass to the place for necropsy, a shocking cetacean explosion incident occurred in the early morning hours on West Gate Road in Tainan City, drawing worldwide attention. The prestigious journal "Nature" even featured a detailed account of the event, and the National Geographic Channel produced a documentary the following year specifically revisiting the site of the cetacean explosion in Tainan City to analyze and reconstruct the Sperm Whale explosion event.

Besides continuously responding to the individual cetacean strandings, the NCKU cetacean team has overseen and handled nearly 30 times mass stranding events in the past 30 years. These mass strandings predominantly occurred along the southwestern coast of Taiwan (includes Pingtung, Kaohsiung and Tainan). The species involved in these mass strandings are predominantly pygmy killer whales (*Feresa attenuat*, 小虎鯨), accounting for over 80% of the incidents.

In 2005, with the fund and supports of the Tainan City Government and the Forestry Bureau of the Council of Agriculture, Executive Yuan, an area within the Sicao Salt Fields in An-Nan District, Tainan, was utilized due to its characteristics of being a tidal flat area with seawater. Existing buildings on-site were refurbished, and adjacent open spaces were developed to construct a large reinforced concrete cetacean rescue pool. This facility, known as the 'Sicao Cetacean Rescue Station,' gradually became the most crucial base in Taiwan's national efforts for stranded cetacean rescue.

Since 1993, the NCKU cetacean team has evolved from initial involvement by professors and students to progressively collaborating with civilian volunteers and various non-governmental organizations. As government attention and implementation of cetacean rescue and conservation policies gradually increased, the Marine Biology and Cetacean Research Center (NCKU MB&CRC) was formally established within National Cheng Kung University in 2009 and has continued to operate to this day.

Start from the initiation of cetacean rescue missions by the NCKU cetacean team in 1993, they have responded to nearly 400 incidents involving approximately 600 stranded cetaceans. Since the establishment of the Sicao Cetacean Rescue Station in 2005, the NCKU MB&CRC team has conducted over 130 tasks involving live stranded cetaceans. Among these, 32 individuals were successfully released back into the wild after intervention on site. Over 10 severely injured cetaceans received comprehensive emergency care, medical treatment, rehabilitation, assessment, and pre-release training at the Sicao Cetacean Rescue Station, enabling them to return to the ocean successfully.

The NCKU cetacean team has been involved in several significant events, such as handling the globally shocking "exploding sperm whale" which is also the largest stranded sperm whale in Taiwan, as well as dealing with Taiwan's first and the world's largest species, the blue whale, which was a death stranded individual on the first day of the Lunar New Year in 2020. For one live strandin event, the NCHU cetacean team managed to rehabilitate a critically ill Risso's dolphin over three months with the help of over 2,200 volunteers, enabling it with “Breaching” and interact in a large rehabilitation pool before processing the releasing it back into the ocean. In collective stranding events primarily occurring in southern Taiwan, the NCKU cetacean team consistently leads and coordinates, directing resources and actively participating in frontline rescue operations.

Preparing for the releasing operation for one pygmy killer whale after 56 days medical cares and rehabilitation.

The NCKU cetacean team has systematically nurtured domestic talents in cetacean rescue through their continuous rescue missions. After each rescue operation, whether involving necropsies or detailed analysis of events, they endeavor to identify the primary causes of cetacean strandings or deaths.

Filtering and analyzing these factors, they compile the data to provide substantial recommendations for national policy adjustments and implementation to the government. Additionally, they appropriately preserve or reconstruct complete skeletal specimens from deceased cetaceans after necropsy, for educational, exhibition, and research purposes. The team remains committed to academic rigor, conducting objective and scientific analyses on cetacean events, physiological conditions, and samples. Through various activities or publications, from popular science articles to academic articles, they have steadily built collaborative relationships with several prominent cetacean entities worldwide, including National Museum of Nature and Science in Japan, non-governmental conservation organizations in South Korea, both academic and non-governmental conservation groups in Philippine, scholars at outstanding universities in New Zealand, cetacean researchers and experts in the university in Hong Kong, museum cetacean team in museum in Sccotland, or top research laboratories in the United States. These collaborations will drive conservation, research, education, talent development, and support for national development, fostering cooperation and fulfilling global conservation and research missions on the cetacean field in the world.

One Risso's dolphin rescuing task in ghe rescue pool of Sicao Cetacean Rescue Station.

Preparing for the releasing operation for one Risso's dolphin after three months' medical cares and rehabilitation in Dec.2020.

Tree Finder – The Giant Tree Map Project

Chi-Kuei Wang,
Professor

Introduction

Chi-Kuei Wang is a professor in the Department of Geomatics at National Cheng Kung University. He earned his bachelor's degree in Agricultural Engineering from National Taiwan University in 1997, and his Master's and Doctoral degrees in Civil and Environmental Engineering from Cornell University in 2003 and 2006, respectively.

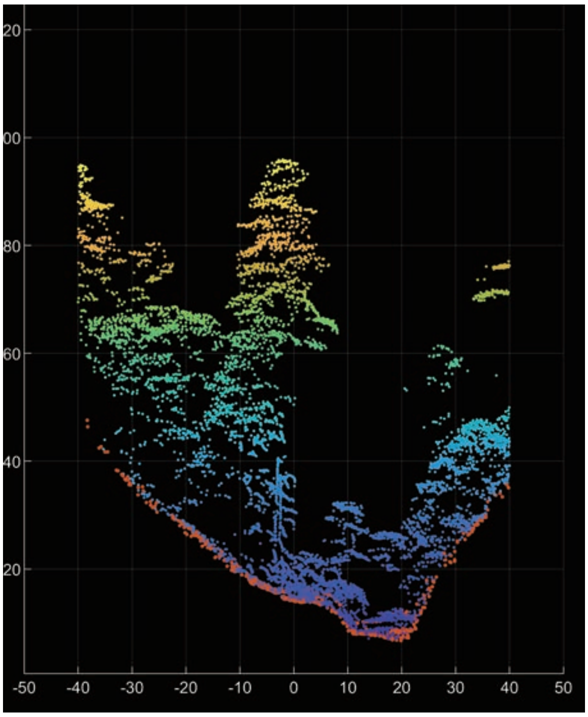
As the principal investigator of the ARSEM (Application of Remote Sensing for Environmental Monitoring) Lab, Dr. Wang focuses on research in terrestrial, mobile, and airborne laser scanning, as well as bathymetric LiDAR. He is also responsible for the QA/QC of Taiwan LiDAR DEM.

The expansive virgin forests that blanket much of Taiwan represent a precious ecological resource. This abundance has prompted a scientific inquiry: Where exactly does Taiwan's tallest tree stand, and what species does it belong to? To address these questions, we have launched the Giant Tree Map Project, an initiative aimed at pinpointing and identifying the tallest tree within Taiwan's lush forests.

Addressing this question demands a collaborative effort from diverse fields of expertise. The journey begins with the data—an extensive set of airborne laser scanning (LiDAR) data collected between 2010 and 2015 by the Central Geological Survey (now part of the Geological Survey and Mining Management Agency) of the Ministry of Economic Affairs, covering the entirety of Taiwan Island. LiDAR technology is the optimal tool for this task, as it captures multiple returns from transmitted laser pulses, illuminating both the canopy and the ground below. Consequently, the resulting 3D point clouds vividly depict the forest landscape. Given our quest for the tallest tree, it is imperative to compile a list of potential candidates to narrow our search. Anticipating that the tallest tree may exceed 70 meters, procedures were devised by members of the ARSEM (Application of Remote Sensing for Environmental Monitoring) Lab in the Geomatics Department of NCKU. These procedures employ a combination of automated algorithms and visual inspections to identify and assess trees exceeding 65 meters, accounting for potential errors inherent in point cloud analysis. Subsequently, this information is transmitted to Dr. Rebecca Hsu at the Taiwan Forestry Research Institute, who leads an expedition team of 10 to 20 members. Their task is to traverse the terrain on foot, scaling the trees to measure and verify their heights. The locations of these giants are situated far from any human activities. Each expedition requires meticulous planning, typically spanning 6 to 12 months. While the expedition team values this information immensely, the point clouds processing is time-consuming and labor-intensive, particularly in processing data for the entirety of Taiwan. Several machine learning-based algorithms were tested, none proved adequate due to the challenging terrain in the most remote regions of Taiwan.

An interesting aspect of this research is the involvement of a dedicated community through our Facebook group, "找樹的人 -Taiwan Champion Trees." Shortly after initiating the search for Taiwan's tallest tree, we established this group to share our progress and engage with the public. The community's support extended beyond news sharing, significantly aiding us in the screening process. We called on volunteers from our Facebook group to assist in processing the data for the entirety of Taiwan Island. To facilitate this, we developed an

The giant tree map



The 2D profile of Kaalang Giant Tree point clouds.

algorithm to generate 2D profiles from the 3D LiDAR point clouds for each potential giant tree location, resulting in 57,000 profiles. Each profile required verification by three volunteers. To our amazement, our 400 volunteers completed the screening within three months! This community effort allowed us to identify a total of 941 verified candidates.

Over the years, several of these trees have been measured and confirmed by the expedition team. As of 2024, the three tallest trees in Taiwan are: Daan River Sword Tree (大安溪倚天劍巨木), standing at 84.1 meters in Taichung City's Daan River; Kaalang Giant Tree (卡阿郎巨木), at 82 meters in the Kaalang River area of Liushunshan; and Taoshan Giant Tree (桃山神木), at 79.1 meters in Taoshan. These discoveries highlight the incredible biodiversity within Taiwan's forests and underscore the importance of combining advanced technology with community engagement in scientific research.

Upcoming airborne LiDAR data of Taiwan Island are continuously being collected by the Department of Land Administration and the National Land Surveying and Mapping Center, both under the Ministry of the Interior. The next phase of the Giant Tree Map Project is to examine the status of these giant trees.

The giant tree map can be found at https://no1tree.tw/

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-Taiwan Champion Trees

台灣巨木地圖
https://no1tree.tw/

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