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RESEARCH DIGEST

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Issue 6

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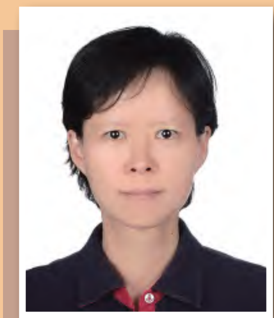
新穎壓電光觸媒 $ZnIn_2S_4$—以永續能源驅動催化產氫

—— 吳季珍，特聘教授
工學院 / 化工系



吳教授於 1997 年獲得國立成功大學化學工程博士學位，隨後於 1997 至 2000 年間在中央研究院原子與分子科學研究所從事博士後研究。2000 年加入國立成功大學化學工程學系擔任助理教授，並於 2006 年升任教授。吳教授的研究專長為新穎奈米結構材料之設計與合成，應用於光電元件、創能技術、儲能系統及綠色製程等領域。近五年來，其研究團隊致力於開發多種先進觸媒系統，包括催化產氫觸媒、光催化儲能觸媒、光催化轉換二氧化碳觸媒、與同步催化產氫與生物質轉換的雙功能觸媒。

本研究首度展示備受矚目的可見光光觸媒 $ZnIn_2S_4$ 具壓電性質，可響應水流之剪切力，而所誘發的壓電勢受其結構中的空缺影響甚鉅。壓電勢產生的巨觀內建電場，有效地抑制光電子與光電洞的再結合，從而顯著地增益 $ZnIn_2S_4$ 光催化水還原產氫效率。

近來具壓電特性的光觸媒受到相當的矚目。壓電勢的存在，可使光觸媒具有巨觀內建電場，有效地驅動光觸媒內部光電子與光電洞的分離和傳輸，從而增益其光催化效率。目前所發表的壓電催化與壓電光催化反應的相關論文，絕大多數以自然界中稀有的超音波震盪提供機械力來驅動壓電效應。然而所謂以超音波震盪來驅動壓電效應之催化反應，已被證實主要是超音波誘發的聲化學反應。若要發展以永續能源驅動之壓電光觸媒，需著眼於對低頻機械能靈敏者，可響應如海潮、渦流、瀑布等天然水資源的流體機械能所誘導剪切力，以結合大自然豐沛的流體機械能與太陽能進行催化反應，進一步將之轉換為化學能。

$ZnIn_2S_4$（ZIS）為近來相當受到矚目的可見光光觸媒，其光催化還原水產氫與二氧化碳轉換之優異效能，已被廣泛地研究與報導。一般文獻認定六方晶體結構的 ZIS 具中心對稱的結晶結構，但部分理論計算的文獻也報導了具空間群 P63mc 的中心非對稱 ZIS 結晶結構，可具有壓電性質。但一直未有討論 ZIS

壓電特性之相關研究發表，更遑論研究其壓電（光）觸媒效能者。

本研究以壓電顯微鏡測量壓電電位響應，證實了有缺陷的非中心對稱 ZIS 具壓電特性。而在以 ZIS 為光觸媒還原水產氫的實驗中，加速使 ZIS 光觸媒在溶液中良好分散的渦旋振動，可顯著地提升 ZIS 光催化產氫速率。探討銦和硫空缺濃度對 ZIS 在還原水產氫的光催化活性影響，觀察到銦和硫空缺濃度與 ZIS 光催化產氫速率之間存在正相關性，與壓電電位響應結果相符。本研究首度以實驗結果證實 ZIS 具壓電性質，並展示其為可響應流體流動之壓電光觸媒，可應用於還原水產氫。

田弘康教授（成功大學化工系）合作團隊以多尺度模擬方法，理論計算分析硫空缺與銦空缺對 ZIS 壓電性質之影響。模擬計算結果支持了隨著硫空缺與銦空缺濃度的增加，可提高 ZIS 壓電性質，增益晶體內部的電場，進而改善光生電子與電洞得分離效率，使得壓電光產氫效能得以提升。

本研究結合實驗與理論計算，首度展示備受矚目的可見光光觸媒 ZIS 具壓電性質，作為可響應流體流動之壓電光觸媒深具潛力。ZIS 可響應可見光與渦流所誘導之剪切力，藉由壓電勢產生的巨觀內建電場，有效地驅動光觸媒內部光電子與光電洞的分離和傳輸，從而顯著地增益其光催化效率。研究也進一步發現 ZIS 的壓電效應與壓電光催化產氫效能，隨晶體中硫空缺與銦空缺濃度的增加而有所提升。本研究藉由對具空缺的非中心對稱 ZIS，進行壓電特性與壓電光催化產氫的全面探索，成功展示可結合大自然豐沛的流體機械能與太陽能進行催化反應，來大幅提高綠色製程之效能。

可同時響應可見光與流體機械能的壓電

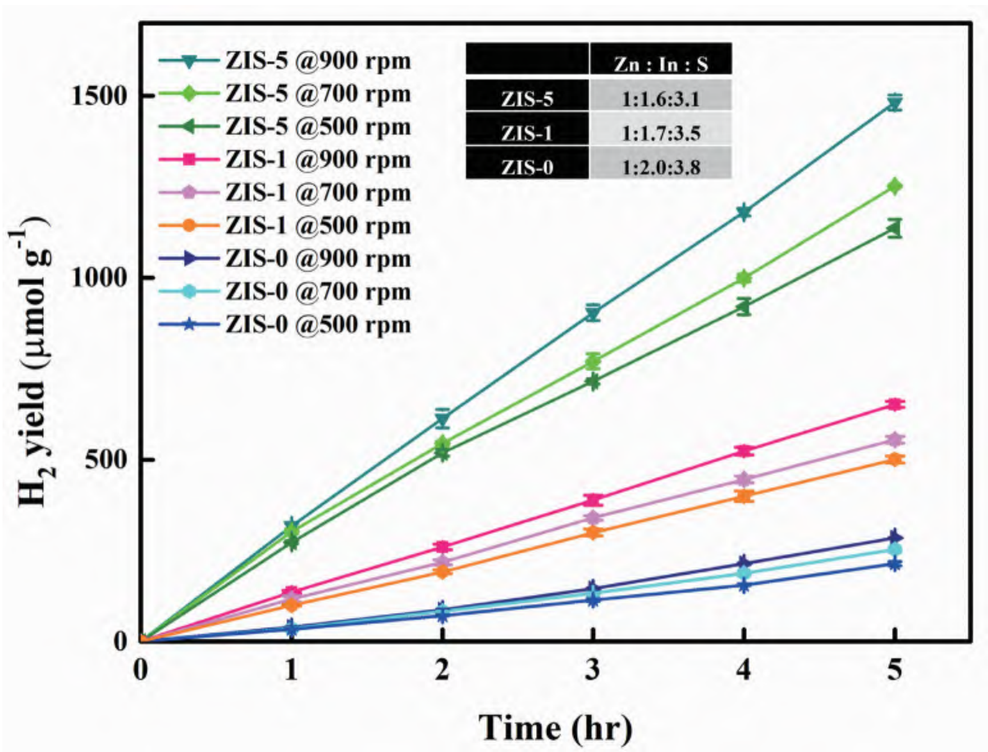


圖 1 缺陷工程增益 $ZnIn_2S_4$ 壓電光催化產氫。

光觸媒，可應用於同步分解水產氫與生物質轉換的還原氧化反應，實現將大自然豐沛的永續再生能源轉換為化學能與化學品之綠色製程。

本研究成功地以 $ZnIn_2S_4$ 為例，成功地開發以永續能源驅動之壓電光觸媒，結合大自然豐沛的流體機械能與太陽能進行催化反應，進一步將之轉換為化學能之重要綠色製程，開創了壓電光觸媒應用的新篇章。

期刊論文

Wen-Jia Zhong, Ming-Yuan Hung, Yen-Ting Kuo, Hong-Kang Tian,* Chih-Ning Tsai, Chien-Jung Wu, Yi-Dong Lin, Hsiang-Chun Yu, Yan-Gu Lin, and Jih-Jen Wu*, Dual-Vacancy-Engineered $ZnIn_2S_4$ Nanosheets for Harnessing Low-Frequency Vibration Induced Piezoelectric Polarization Coupled with Static Dipole Field to Enhance Photocatalytic H_2 Evolution, Adv. Mater., 2403228, 2024. https://doi.org/10.1002/adma.202403228.

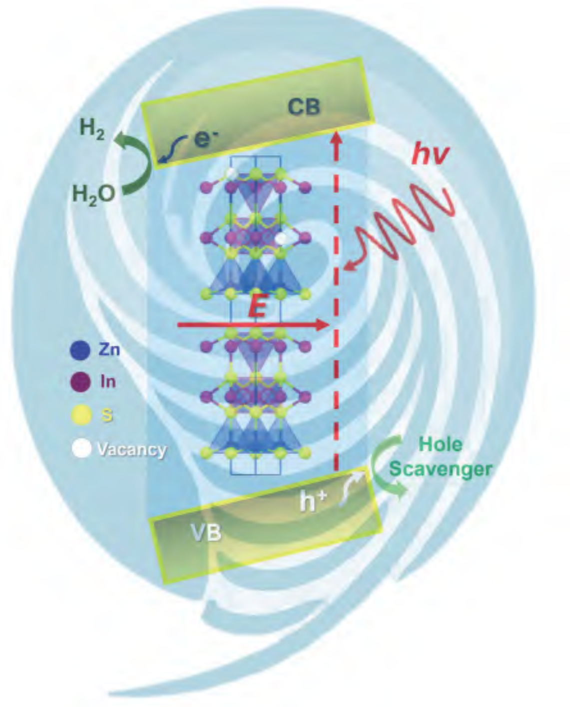
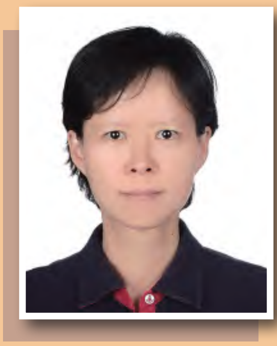


圖 2 以可見光與渦流所誘導之剪切力驅動 $ZnIn_2S_4$ 催化產氫之示意圖。

Novel $ZnIn_2S_4$-Based Piezophotocatalysts for Sustainable Energy-Driven Hydrogen Production

Jih-Jen Wu, Distinguished Professor
College of Engineering, Department of Chemical Engineering



Professor Wu received her Ph.D. in Chemical Engineering from National Cheng Kung University, Taiwan, in 1997. She then pursued postdoctoral research at the Institute of Atomic and Molecular Sciences, Academia Sinica, Taiwan, from 1997 to 2000. In 2000, she joined the Department of Chemical Engineering at National Cheng Kung University as an assistant professor and was promoted to full professor in 2006. Professor Wu's research focuses on the design and synthesis of nanostructured materials for sustainable energy conversion, biomass valorization, energy storage, and optoelectronic applications. In recent years, her group has developed various advanced photocatalytic, piezophotocatalytic, and electrochemical catalytic systems for hydrogen production, CO_2 conversion, and biomass upgrading.

This study demonstrates, for the first time, that the widely investigated visible-light photocatalyst $ZnIn_2S_4$ exhibits piezoelectric behavior and is capable of responding to shear forces induced by fluid motion. The magnitude of the piezoelectric potential in $ZnIn_2S_4$ is highly tunable through structural vacancy engineering. The resulting macroscopic built-in electric field effectively suppresses the recombination of photogenerated electron–hole pairs, thereby significantly enhancing the photocatalytic activity for hydrogen evolution.

Recently, photocatalysts with piezoelectric properties have garnered considerable attention. The presence of a piezoelectric potential can induce a macroscopic built-in electric field within the photocatalyst, which effectively promotes the separation and transport of photogenerated electron–hole pairs, thereby enhancing photocatalytic efficiency. Most of the reported studies on piezo-photocatalysis rely on mechanical stimulation provided by ultrasonic vibration, which is not universally available in nature, to activate the piezoelectric effect. However, it has been demonstrated that catalytic reactions driven by ultrasonic excitation are predominantly governed by sonochemical effects rather than genuine piezoelectric mechanisms. To advance the development of sustainable energy-driven piezo-photocatalysts, it is essential to focus on materials that are sensitive to low-frequency mechanical stimuli. Such materials should be capable of responding to shear forces induced by naturally abundant fluidic mechanical energy sources, such as ocean tides, vortices, and waterfalls. Harnessing these renewable sources in conjunction with solar energy offers a promising strategy for converting natural energy inputs into chemical energy through catalysis.

$ZnIn_2S_4$ (ZIS) has recently emerged as a highly promising visible-light photocatalyst, widely studied for its outstanding performance in photocatalytic hydrogen evolution from water and CO_2 reduction. While the hexagonal crystal structure of ZIS is generally recognized in the literature as centrosymmetric, some theoretical studies have proposed a non-centrosymmetric crystal structure with space group P63mc, which could endow ZIS with piezoelectric properties. However, to date, there have been no experimental investigations reporting on the piezoelectric behavior of ZIS, let alone studies exploring its piezoelectric (photo) catalytic performance.

In this work, the piezoelectric characteristic of the defective ZIS is observed through the piezopotential response measured using piezoelectric force microscopy, providing the first experimental confirmation of its intrinsic piezoelectric properties. In photocatalytic hydrogen evolution reaction (HER) experiments, the piezoelectric polarization, stimulated by low-frequency vortex vibration to ensure the well-dispersion of ZIS in solution, plays a crucial role in enhancing photocatalytic HER over the dual-vacancy engineered ZIS nanosheets. The impact of In- and S-vacancy concentrations on the photocatalytic activity of ZIS for HER was also investigated in this work. A positive correlation between the concentrations of dual In and S vacancies and the photocatalytic HER rate over ZIS is observed, consistent with the trend in piezoelectric potential response.

To complement the experimental findings, a collaborative team led by Professor Hong-Kang Tian from the Department of Chemical Engineering at National Cheng Kung University performed multiscale simulations to theoretically evaluate the impact of sulfur and indium vacancies on the piezoelectric behavior of ZIS. The simulations support the experimental observations, showing that increasing vacancy concentrations enhance the internal electric field via amplified piezoelectric polarization. This enhancement facilitates more efficient separation of photogenerated charge carriers, thereby boosting the overall piezoelectric-assisted photocatalytic hydrogen evolution performance.

This study integrates experimental investigations with theoretical calculations to demonstrate, for the first time, that the widely studied visible-light photocatalyst ZIS possesses intrinsic piezoelectric properties, establishing its promising potential as a piezoelectric photocatalyst responsive to fluid flow. ZIS is capable of responding to shear forces induced by vortex motion, generating a macroscopic built-in electric field through piezoelectric potential. This internal field effectively promotes the separation and transport of photogenerated electron-hole pairs, thereby significantly enhancing its photocatalytic efficiency. Furthermore, the study reveals that the piezoelectric response and the piezophotocatalytic hydrogen evolution performance of ZIS are positively correlated with the concentration of sulfur and indium vacancies within the crystal structure. Through a comprehensive investigation of defective non-centrosymmetric ZIS, this work successfully demonstrates the feasibility of coupling naturally abundant fluidic mechanical energy with solar energy to drive highly efficient catalytic reactions.

Piezophotocatalysts capable of simultaneously responding to visible light and fluidic mechanical energy offer promising applications in coupled redox reactions, such as concurrent water splitting for hydrogen production and biomass conversion. This approach enables the sustainable transformation of abundant natural renewable energy sources into chemical energy and value-added chemicals, paving the way for green and efficient chemical manufacturing processes.

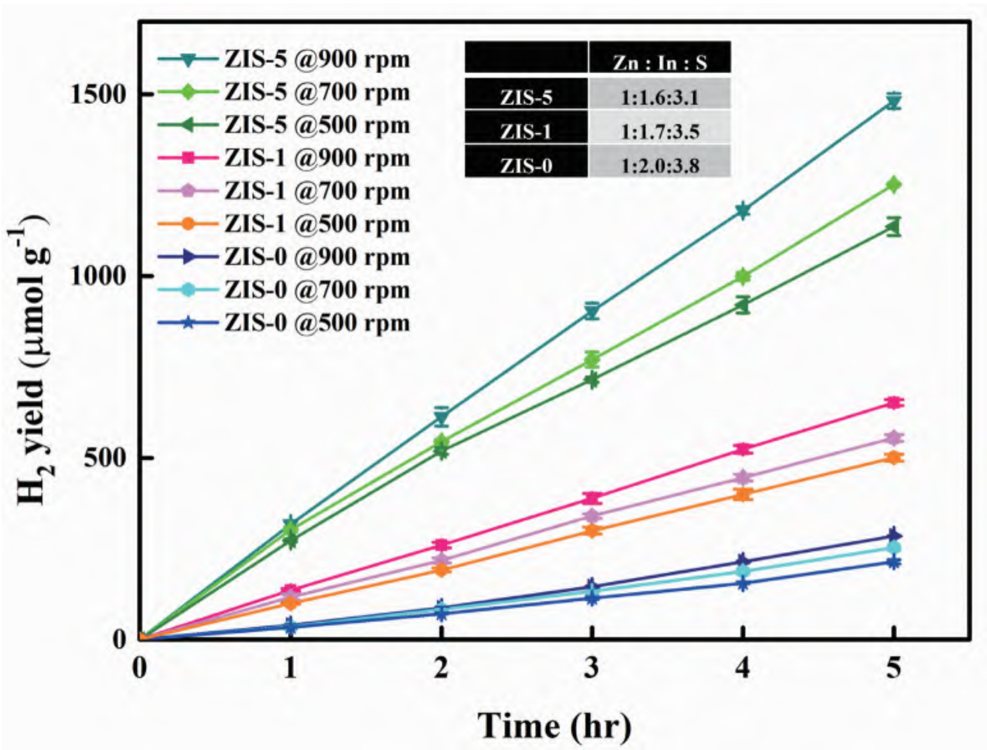


Fig. 1 Hydrogen evolution over Dual-Vacancy-Engineered $ZnIn_2S_4$ under illumination coupled with vortex vibration at different speeds.

In this study, $ZnIn_2S_4$ is successfully demonstrated as a model system for the development of a sustainable energy-driven piezoelectric photocatalyst. By harnessing naturally abundant fluidic mechanical energy in conjunction with solar energy, catalytic reactions are effectively facilitated for energy and chemical conversions, representing a significant advancement in green chemical processing. This work opens a new chapter in the application of piezophotocatalysis for sustainable energy conversion.

Journal Paper

Wen-Jia Zhong, Ming-Yuan Hung, Yen-Ting Kuo, Hong-Kang Tian,* Chih-Ning Tsai, Chien-Jung Wu, Yi-Dong Lin, Hsiang-Chun Yu, Yan-Gu Lin, and Jih-Jen Wu*, Dual-Vacancy-Engineered $ZnIn_2S_4$ Nanosheets for Harnessing Low-Frequency Vibration Induced Piezoelectric Polarization Coupled with Static Dipole Field to Enhance Photocatalytic H_2 Evolution, Adv. Mater., 2403228, 2024. https://doi.org/10.1002/adma.202403228.

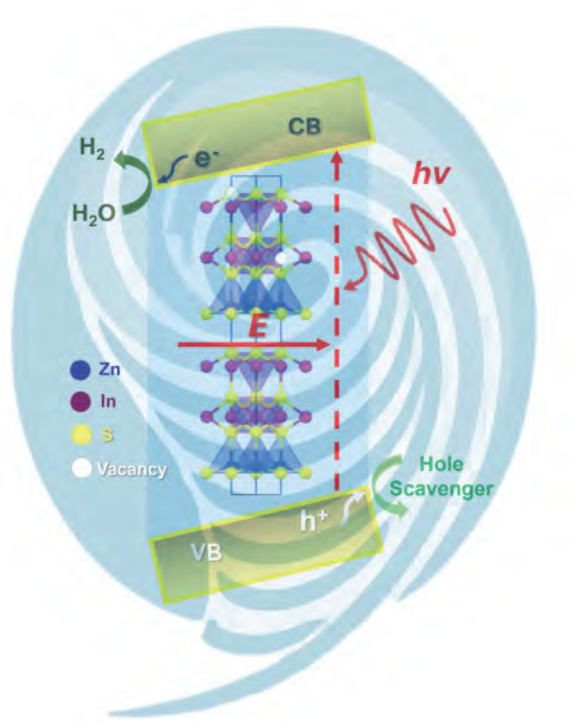


Fig. 2 Schematic of the catalytic hydrogen production over $ZnIn_2S_4$ driven by visible light and vortex-induced shear force.

次世代顯示技術與智慧生醫系統之研發與應用

林志隆，特聘教授
電機資訊學院 / 電機工程學系

林志隆特聘教授之研究聚焦在 Micro-LED 驅動架構、AMOLED 亮度補償及生醫光電應用，包含低功耗驅動電路與 AI 演算法顯示與老人與傷口照護醫療系統。成果包括防漏電之主動式 CMOS Micro-LED 顯示器、基於 AI 之 AMOLED 亮度預測及補償技術與多光譜傷口癒合預測系統。

林志隆特聘教授長期致力於平面顯示科技與生醫光電系統之創新技術開發，聚焦於新世代顯示器驅動架構、智慧型影像補償系統、AR/VR 顯示器以及結合人工智慧之生醫光電應用等領域。透過跨領域合作與產學連結，成功發展具國際競爭力之技術成果，不僅發表於多篇國際頂尖期刊，亦榮獲多項國際學術榮譽與產業界高度肯定。林志隆特聘教授之研究以 Micro-LED 及 AMOLED 顯示面板、前瞻微型顯示器架構和生醫光電系統為主軸，近三年發表期刊於 Advances in Optics and Photonics、Light: Science & Applications、IEEE TED、IEEE TIE 等頂尖期刊，專利累計 95 件，技術轉移金額達 225 萬元，並獲 Optica Fellow、SID Fellow 與 IET Fellow 等國際肯定。

在 Mini/Micro-LED 方面，林教授團隊提出新式 Micro-LED 驅動系統，可大幅提升發光效率減少面板功耗，同時簡化 PWM 驅動畫素電路所需的複雜驅動波形，使面板系統架構更精簡，此外林教授亦對車用 Mini-LED 背光顯示器在高環境光下辨識度下降的議題提出補償方式，透過計算符合人眼方程之 gamma 係數，使顯示畫面在太陽光（100k lux）照射下仍可辨識畫面細節。

在 AR/VR 顯示電路方面，林教授針對畫素尺寸過小導致漏電流易影響顯示灰階之議

題，開發具防漏電架構之主動式矩陣 CMOS 微型電路，改善傳統電路驅動電流易隨時間產生偏移的問題。在新式 AMOLED 外部補償機制方面，林教授將人工智慧應用於 AMOLED 顯示器，透過開發類神經網路並建立演算法來預測 AMOLED 顯示器亮度衰退的趨勢，並將演算法實現於 FPGA 上以達到亮度補償的功能之 Demura 與 Deburn-in 補償機制。

在前瞻生醫光電電子系統方面，林教授設計多光譜 LED 電路並結合影像感測器，藉由不同波長之光譜對血紅素的吸收差異取得傷口組織皮下血氧濃度，也導入深度學習模型判斷傷口區域，提出世界第一個結合可見光與多光譜成像的慢性傷口癒合預測系統，利於醫護人員客觀分析傷口癒合狀態。林教授亦整合光學測距感測器與鞋型穿戴式裝置，透過人工智慧模型分析行走步伐高度及障礙物的偵測，達到日常生活動作、絆倒與跌倒等多種類別的辨識，可即時感知危險事件的發生並通報相關人員以最大程度減輕跌倒傷害。

林教授於 Micro-LED 驅動架構上首創內建鋸齒波產生功能之脈衝寬度調變之畫素電路 [1]，提升發光效率並簡化系統，相關技術已獲美國專利 [2]，並應用於友達之低溫多晶矽面板。此外，林教授與瑞鼎公司合作，開發防漏電之主動式矩陣 CMOS Micro-LED 微型顯示器（7000 PPI、單畫素 3.6μm×3.6μm），並已完成面板實作及 Micro-LED bonding。針對 AMOLED 之亮度衰退與低頻操作問題，首次提出 Demura 與 Deburn-in 電路補償技術，實際實現於 1.41 吋 AMOLED 面板，有效降低驅動功耗逾 2 倍 [3]。於生醫系統方面，林教授開發結合可見光與多光譜影像之傷口癒合預測系統 [4]，且分割準確度達 94%，並提出鞋型穿戴式跌倒預警裝置 [5]，其平均準確率達 98%，證明提出系統之可靠度。

未來，林教授希冀持續強化跨領域整合能力，開發次世代可撓式與透明 Micro-LED 顯示技術，進一步提升穿戴式與車載應用之功能與視覺體驗，並持續發展生醫系統之傷口與老人照護平台，進一步結合臨床數據與 AI 模型實現預測式健康照護。

林教授整合顯示電路設計、生醫光電感測、人工智慧演算法與系統整合等跨領域技術，推動多項具有突破性的研究成果，並成功應用於次世代顯示器與智慧醫療系統。研究成果不僅提升國內科技自主研發能力，亦獲得國際學術與產業界廣泛肯定與引用。林教授未來將持續投入關鍵技術創新，深化產學合作，拓展研究應用面向，為我國在智慧顯示與生醫科技領域建立國際領導地位貢獻心力。

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[2] 林志隆，林捷安，鄧名揚，吳佳恩 “Pixel compensation circuit” US 發明 US11170706B1 2021/11/09

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[4] Chih-Lung Lin*, Meng-Hsuan Wu, Yuan-Hao Ho, Fang-Yi Lin, Yu-Hsien Lu, Yuan-Yu Hsueh, and Chia-Chen Chen, “Multispectral Imaging-based System for Detecting Tissue Oxygen Saturation with Wound Segmentation for Monitoring Wound Healing,” IEEE Journal of Translational Engineering in Health and

Medicine, vol. 12, pp. 468-479, May. 2024. (Impact Factor: 3.7) DOI: 10.1109/JTEHM.2024.3399232)

[5] Chih-Lung Lin*, Yuan-Hao Ho, Fang-Yi Lin, Pi-Shan Sung, and Cheng-Yi Huang, “Fall-Risk Monitoring in Diverse Terrains Using Dual-Task Learning and Wearable Sensing System,” IEEE Journal of Biomedical and Health Informatics, Jan. 2025 (Impact Factor: 6.7)

Development and Application of Next-Generation Display Technologies and Intelligent Biomedical Systems

Chih-Lung Lin, Distinguished Professor
College of Electrical Engineering and Computer Science, Department of Electrical Engineering

Professor Chih-Lung Lin's research focuses on Micro-LED driving structure, AMOLED brightness compensation, and biomedical optoelectronic applications, including low-power driving circuits, AI algorithms for display, and healthcare systems for elderly care and wound care. His achievements include a leakage-prevention active-matrix CMOS Micro-LED display, AI-based AMOLED brightness prediction and compensation technology, and a multispectral wound healing prediction system.

Professor Chih-Lung Lin has been dedicated to the innovative development of flat panel display technologies and biomedical optoelectronic systems, with a focus on next-generation display driving schemes, intelligent image compensation systems, AR/VR displays, and AI-integrated biomedical electronic applications. Through interdisciplinary collaboration and strong industry-academia cooperation, he has successfully developed internationally competitive technologies that have been published in distinguished journals and recognized with prestigious academic honors. His research focuses on Micro-LED and AMOLED display panels, advanced micro-display architectures, and biomedical electronic systems. In the past three years, his work has been published in highly-ranked journals such as Advances in Optics and Photonics, Light: Science & Applications, IEEE Transactions on Electron Devices (TED), and IEEE Transactions on Industrial Electronics (TIE). He has received a total of 95 patents, technology transfer worth NT$2.25 million, and international recognition as an Optica Fellow, SID Fellow, and IET Fellow.

In the field of Mini/Micro-LED, Professor Lin's team has developed a novel Micro-LED driving system that significantly enhances luminous efficiency and reduces the power consumption of the panel, while simplifying the complex waveforms required pulse-width modulation (PWM) pixel circuits, and thus reduces the complexity of panel system. Additionally, he proposed a compensation method for automotive Mini-LED backlight displays to address the visibility under high ambient light conditions. By calculating gamma coefficients based on human eye just-noticeable difference, the display remains clearly visible even under direct sunlight (100k lux).

In AR/VR display circuits, Professor Lin tackled the issue of leakage current affecting grayscale levels due to ultra-small pixel sizes by designing active-matrix CMOS circuits with leakage-prevention structures, improving the stability of driving currents. For AMOLED displays, he introduced a new external compensation mechanism by applying artificial intelligence. Using neural networks and predictive algorithms to model brightness degradation trends, the system was implemented on FPGA hardware to enable effective Demura and Deburn-in brightness compensation.

In advanced biomedical systems, Professor Lin developed multispectral LED circuits integrated with multispectral sensors. By leveraging the spectral absorption differences of oxyhemoglobin and deoxyhemoglobin at specific wavelengths, the system detects cutaneous oxygen saturation in wound tissue. He also introduced deep learning models to identify wound areas, leading to the world's first predictive healing system for chronic wounds that combines visible and multispectral images empowering healthcare providers to objectively assess wound healing phases. Moreover, Professor Lin integrated optical distance sensors into a shoe-type wearable device that analyzes gait types and detects terrain types. By integrating with AI models, the system enables real-time recognition of various daily activities and incidents such as tripping and falling, allowing immediate alerts to reduce injury risks.

Professor Lin is the first to propose the novel Micro-LED driving structure featuring a built-in sawtooth-like wave generators for PWM pixel circuits [1], enhancing luminous efficiency and simplifying system complexity. This technology has been granted a U.S. patent [2] and applied to AUO's low-temperature polysilicon display panels. In collaboration with Raydium Semiconductor, he also developed a CMOS-based active-matrix Micro-LED display with leakage prevention structure (7000 PPI, pixel size of 3.6 μm × 3.6 μm), and fabricated Micro-LED display panels.

To address brightness degradation and low-frequency operation issues in AMOLED displays, Professor Lin is the first to propose Demura and Deburn-in compensation circuits, which were successfully implemented in a 1.41-inch AMOLED panel, achieving over 50% reduction in power consumption [3].

In the biomedical domain, he developed a predictive wound healing system that integrates visible and multispectral imaging, achieving a segmentation accuracy of 94% [4]. Additionally, he proposed a shoe-type wearable fall-prevention system [5], which demonstrated an average accuracy of 98%, validating the high reliability of the proposed system.

In the future, Professor Lin aims to further strengthen interdisciplinary integration to develop next-generation flexible and transparent Micro-LED display technologies, enhancing both functionality and visual experience for wearable and vehicle applications. He also plans to advance biomedical systems focused on wound care and elderly care platforms, integrating clinical data with AI models to realize predictive healthcare solutions.

Professor Lin has integrated interdisciplinary technologies, including display circuit design, biomedical optoelectronic sensing, AI algorithms, and system integration, to drive numerous groundbreaking research achievements. These innovations have been successfully applied to next-generation display systems and smart healthcare technologies. His work has enhanced domestic capabilities in independent research and gained wide recognition and citation from the international academic and industrial communities. Moving forward, he will continue advancing key technological innovations, deepening academia-industry collaborations, and expanding the application scope of his research to help establish Taiwan's international leadership in smart display and biomedical technologies.

Journal Paper

[1] Chih-Lung Lin*, Cheng-Han Ke, Jui-Hung Chang, Chieh-An Lin, Chia-En Wu, and Ming-Hsien Lee, "Analog PWM Method With Sweep Generation Structure Based on P-Type LTPS TFTs for Micro-LED Displays," IEEE Journal of the Electron Devices Society, Oct. 2023. (Impact Factor: 2) DOI: 10.1109/JEDS.2023.3324065132

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軸冷式馬達場分析

——張始偉，特聘教授
工學院 / 系統及船舶機電系

張始偉 2017 年於系統及船舶機電工程系擔任專任教授，2021 年聘任為特聘教授。自 2003 年擔任 TAF 測試實驗室（0895）負責人，曾任臺灣給排水研究學會理事長。於 1992 年獲英國威爾斯大學 Swansea 分校學士學位（First Class），1995 年獲博士學位，2010 年獲科學博士學位。攻讀博士期間（1992-1995），獲英國政府 Overseas Research Scholarship。主要研究領域包括熱傳強化、燃氣渦輪機定、動葉冷卻、活塞冷卻、電子冷卻、馬達散熱、海象熱流研究、二相流及熱傳，已發表 160 多篇 SCI 期刊論文，曾獲國科會傑出研究獎兩次。

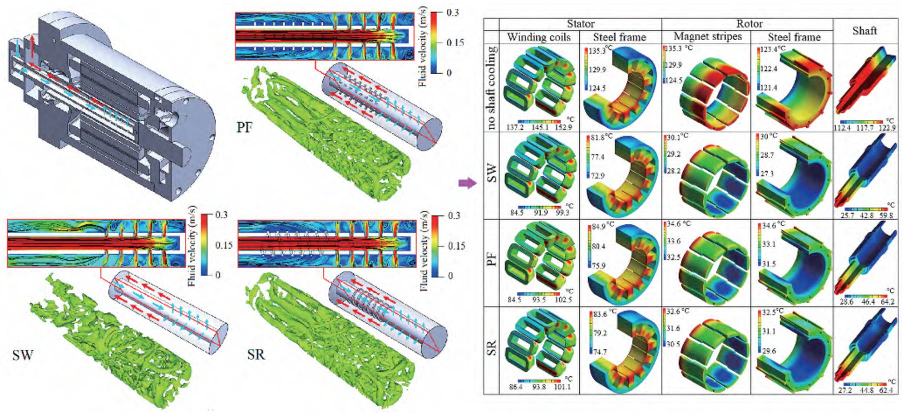
馬達熱功率隨轉速、轉矩、效率改變，內部熱對流性能受轉子（軸）之旋轉影響，精準熱場模擬困難，散熱技術為避免熱損害關鍵。應用衝擊噴柱及紊流產生器提升軸冷效益，助益馬達功率密度持續提升，強化競爭優勢。

各式綠能通常轉換成電能，再經馬達輸出動力。馬達競爭優勢與其功率密度相關，惟提高馬功率密度之關鍵為其散熱技術，且馬達由多樣性之複合構造組成，內部諸多氣室形狀複雜，其對流強度亦受旋轉構件影響，精準之三維熱場模擬困難。發展熱傳強化技術及精準評估其冷卻效益，構成馬達冷卻研究之主流。

相較於未設軸冷之馬達，本研究開發之強化軸冷技術分別降低定子線圈與轉子磁條最高溫 30.16-35.2% 及 69.73-75.7%，確認其優異之冷卻效益，使得馬達功率密度得以提升。

除適用馬達某軸端聯結機械負載之馬達散熱外，此技術可應用於各式旋轉機械之轉軸冷卻。

散熱研究為開發高性能馬達之核心技術之一，本研究與台達電之電磁領域工程師跨域合作完成，產學共研核心技術問題，除能確保工程領域之研究水準，更能強化學術研究之擴散效益，貢獻社會。



馬達中空轉軸中裝設噴柱管，下游區域使用螺旋鰭片或柱鰭陣列改變冷卻流體於旋轉中空軸之流場結構，提升冷卻效益。應用本團隊開發之馬達三維熱場模擬技術，經實驗確證準確度，證明此軸冷強化技術顯著降低定子線圈與矽鋼片及轉子與其磁條之溫度。

期刊論文

Shyy Woei Chang and Wei Ling Cai, Thermal impact of integrated bore cooling with impinging jets and turbulators in rotating shaft of interior permanent magnet electric motor, Thermal Science and Engineering Progress, 57, 103164.

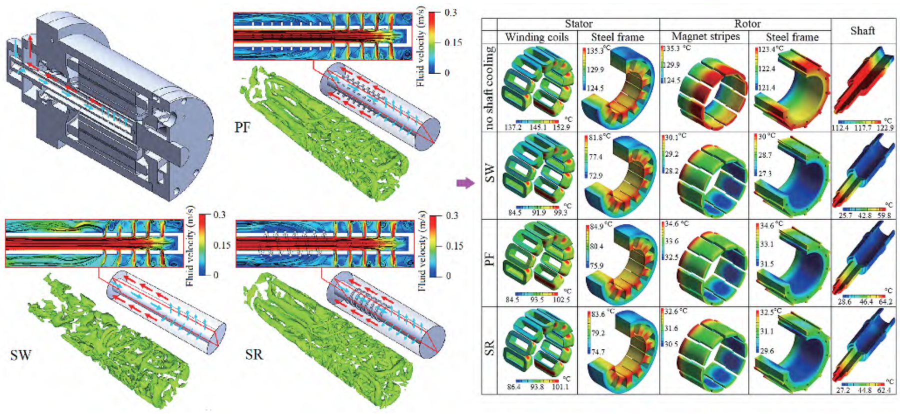
Thermal analysis of electric motor with shaft cooling

Shyy Woei Chang, Distinguished Professor
College of Engineering, Department of Systems and Mechatronic Engineering

He was appointed as a professor in NCKU in 2017 and was appointed as a distinguished professor in 2021. Since 2003, he has served as the head of TAF Testing Laboratory (0895) and served as the chairman of the Taiwan Water Supply and Drainage Society. He received his B.A. (First Class) from University of Wales (Swansea) in 1992, Ph.D. in 1995 and Dsc. in 2010. During his Ph.D. studies (1992-1995), he was awarded the Overseas Research Scholarship by the British Government. His research interests include heat transfer enhancement, gas turbine blade cooling, piston cooling, electronic cooling, motor heat dissipation, thermos-fluids in sea conditions, two-phase flow and heat transfer. He has published more than 160 SCI journal papers and won the Outstanding Research Award of the National Science and Technology Council twice.

Thermal powers of motor vary with speed, torque and efficiency. Internal convective flows are affected by rotations of rotor and shaft, posing difficulties in thermal simulation. Cooling technology is crucial for avoiding its thermal damage. Promoting cooling efficacy by impinging jets and turbulators in rotating shaft permits ever-mounting power density, strengthening competitive advantages of motor.

Green energy is usually converted into electricity and transformed as power via motor. Competitive advantages of a motor are pertinent to its power density; while the key to increasing power density lies in cooling technology. A motor is composed of a variety of composite structures with internal air chambers of complex configurations. Heat convection in an air chamber is influenced by its constituent rotating components, leading great challenge for accurate three dimensional thermal simulations. Development of heat transfer enhancement technology with computational capabilities for accurately evaluating its cooling efficacy manifest motor cooling research.



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With present cooling enhancement schemes in shaft, the maximum coil and magnet temperatures are reduced by 30.16-35.2% and 69.73-75.7% of those without shaft cooling respectively, affirming the favorable cooling impacts for permitting increases of power density of motor.

In addition to the cooling application for a motor connecting with mechanical load at one shaft end, this technology remains applicable to shaft cooling of various rotating machineries.

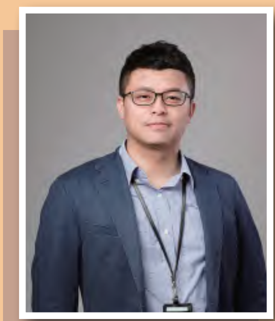
Cooling research is one of the core technologies for developing high-performance motors. This research is completed through multidiscipline cooperation with engineers in the electromagnetic field of Delta Electric. The industry-academia joint research on core technological issues can not only ensure the research quality in the engineering field, but also strengthen the spreading benefits of academic research, leading to social contributions.

Journal Paper

Shyy Woei Chang and Wei Ling Cai, Thermal impact of integrated bore cooling with impinging jets and turbulators in rotating shaft of interior permanent magnet electric motor, Thermal Science and Engineering Progress, 57, 103164.

因果推論：真實世界數據研究的核心與學術價值永續的推動力

—— 賴嘉鎮，教授
醫學院 / 藥學系



賴嘉鎮教授運用台灣真實世界數據，結合臨床情境與藥物流行病學研究設計，從「觀察現象」到驗證研究議題中的「因果關係」。他所領導的群體健康數據中心團隊，近年來積極開發進階研究設計與統計模型，致力提升真實世界數據研究的可信度與影響力，為治療策略的制定提供可靠的證據。賴教授已發表近 150 篇學術論文，並獲國科會 2030 跨世代國際年輕傑出學者計畫多年期補助，積極推動跨領域研究及全球永續發展相關計畫。他參與亞洲藥物流行病學網（AsPEN）和 NeuroGEN 等國際組織計畫，致力於搭建國際研究平台，促進學術交流與政策改善，進一步提升台灣在全球真實世界數據研究的領導地位，實現「Taiwan can help」到「Taiwan can lead」的願景。

因果推論是醫學與公共衛生研究中不可或缺的方法，尤其在真實世界數據的分析中具有重要地位。本文以實例說明因果推論的應用，並探討其在醫療政策與臨床決策上的價值與未來展望。

在醫學與公共衛生領域，因果推論是一項不可或缺的研究工具，尤其在真實世界數

據的分析中更為重要。當我們觀察到某種暴露與結果之間的關聯性時，這種關聯並不等同於因果關係，因為真實世界數據往往受到適應症干擾或反向因果偏差等因素影響。

在我們過去的研究中，我們使用自我控制案例系列法（SCCS），以個人為單位分析抗精神病藥物與跌倒骨折的關聯性。初步比較治療中與未治療區間的發生率時，發現有顯著增加趨勢。然而，觀察治療前 14 天的區間，事件發生率更高，顯示適應症干擾可能是主要原因。另一項研究中，我們運用「未來病例交叉設計」，探討抗膽鹼負荷與主要心血管事件的風險，在考慮並校正隨時間變化的偏差後，此相關性仍存在，進一步證實了兩者之間的關聯性。

這些研究例證凸顯了因果推論在釐清複雜關係中的關鍵角色，避免錯誤結論影響臨床及政策決策。

近年來，隨著美國「21 世紀醫療法案」及歐盟「Horizon 2020 計畫」的推動，真實世界分析逐漸成為醫藥審查的重要輔助工具。若能妥善運用因果推論並結合真實世界數據，不僅能評估台灣本土狀況以應用於臨床照護，亦有助於醫療資源分配、減少不必要干預、降低臨床試驗成本，並提升健康公平性，有助於醫療照護永續發展。

因此，因果推論不僅是學術研究技術，更是實現永續的重要推力。透過嚴謹推論過程，確保研究可靠性與再現性，避免錯誤證據，提升學術資源利用效率，持續為醫療與公共健康的永續發展而努力。

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1.Wang GH, Man KKC, Chang WH, Liao TC, Lai EC. Use of antipsychotic drugs and cholinesterase inhibitors and risk of falls and fractures: self-controlled case series. BMJ. Sep 9 2021;374:n1925. doi:10.1136/bmj.n1925

2.Huang WC, Yang AS, Tsai DH, Shao SC, Lin SJ, Lai EC. Association between recently raised anticholinergic burden and risk of acute cardiovascular events: nationwide case-case-time-control study. BMJ. Sep 27 2023;382:e076045. doi:10.1136/bmj-2023-076045

3.21 Century Cures Act: https://www.fda.gov/regulatory-information/selected-amendments-fdc-act/21st-century-cures-act

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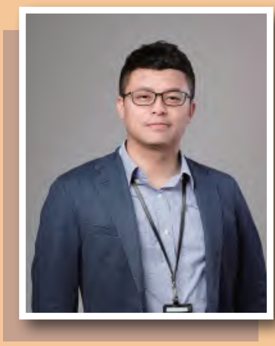
Causal Inference: The Core of Real-World Data Research and a Sustainable Driving Force for Academic Value



Edward Chia-Cheng Lai, Professor
College of Medicine,
School of Pharmacy

Professor Edward Chia-Cheng Lai leverages real-world data from Taiwan, integrating clinical contexts with pharmacoepidemiologic research designs to transition from observing phenomena to establishing causal relationships in research. Under his leadership, the Population Health Data Center has been actively developing advanced research designs and statistical models, striving to enhance the credibility and impact of real-world data research and provide robust evidence for treatment strategy development. Professor Lai has published nearly 150 academic papers and received long-term funding from the National Science and Technology Council's 2030 Cross-Generational International Young Scholars Program, actively promoting interdisciplinary research and global sustainability initiatives. He is involved in international research networks such as the Asian Pharmacoepidemiology Network (AsPEN) and NeuroGEN, dedicated to building international research platforms, promoting academic exchanges and policy improvements. Through these efforts, he continues to enhance Taiwan's leadership in global real-world data research, realizing the vision from "Taiwan can help" to "Taiwan can lead."

Causal inference is an essential methodology in medical and public health research, particularly in the analysis of real-world data. This article illustrates the application of causal inference through examples and discusses its value in healthcare policy, clinical decision-making, and future prospects.

In the fields of medicine and public health, causal inference is an indispensable research tool, particularly crucial when analyzing real-world data. Observed associations between exposures and outcomes do not necessarily indicate causal relationships, as real-world data are often influenced by confounding by indication or reverse causation.

In our previous studies, we applied the self-controlled case series (SCCS) method to analyze the association between antipsychotics and fall-related fractures. While comparing incidence rates between treatment and non-treatment periods revealed an increasing trend, a much higher incidence rate was observed during the 14 days prior to treatment, indicating confounding by indication. Another study employed the case-crossover design to investigate the association between anticholinergic burden and major cardiovascular events. After accounting for temporal bias, the relationship still remained and was further confirmed.

These examples highlight the critical role of causal inference in clarifying complex associations and avoiding erroneous conclusions that could impact clinical practice and policymaking.

In recent years, with the promotion of the 21st Century Cures Act in the United States and the Horizon 2020 program in the European Union, real-world data analysis has increasingly become an essential component of pharmaceutical review processes. Proper application of causal inference combined with real-world data can not only assess local healthcare conditions for clinical application in Taiwan but also facilitate better resource allocation, reduce unnecessary interventions, lower clinical trial costs, and enhance health equity, contributing to the sustainable development of healthcare systems.

Therefore, causal inference is not only a research technique but also a driving force for sustainability.Through rigorous inference processes, we can ensure the reliability and reproducibility of research findings, avoid erroneous evidence, and enhance the efficient use of academic resources, continuously contributing to the sustainable development of healthcare and public health.

Reference

1.Wang GH, Man KKC, Chang WH, Liao TC, Lai EC. Use of antipsychotic drugs and cholinesterase inhibitors and risk of falls and fractures: self-controlled case series. BMJ. Sep 9 2021;374:n1925. doi:10.1136/bmj.n1925

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3.21 Century Cures Act: https://www.fda.gov/regulatory-information/selected-amendments-fdc-act/21st-century-cures-act

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跨域創新實踐：電動載具、太空科技與 AI 智能應用

—— 謝旻甫，特聘教授
電機資訊學院 / 電機工程學系

電機系謝旻甫特聘教授主持「電機與驅動系統研究室」，曾兼任副研發長。專長於高性能電機設計與智慧驅動系統。近年主導多項計畫，包括寬能隙元件應用於高性能馬達驅動器、高功率密度伺服馬達與 AI 智慧故障診斷演算法等。透過與業界夥伴合作，推動高功率電動車馬達與衛星反應輪等自主化成果，強化台灣在電動載具與太空科技領域的研發能量。謝教授亦長期參與 IEEE 國際事議與期刊編輯，積極鏈結國際資源，致力培育具國際競爭力的高階人才。

本團隊聚焦電機設計與驅動、電動載具、衛星姿態控制與 AI 故障診斷技術，推動台灣自主技術發展、培育高階科研人才。與中鋼合作開發高性能電動車馬達，並與國家太空中心研製國產反應輪，且 AI 診斷成果獲國際肯定。

從太空到地面，科技的未竟之夢

在太空、電動車及國防自主等領域快速發展下，儘管台灣具備堅實產業基礎，關鍵技術與核心零組件多仍依賴國際供應，導致高成本與技術斷層風險。為實現「技術自主」目標，研究團隊長期投入高性能電機與馬達驅動技術研發，涵蓋馬達設計、載具動力系統、驅動控制與 AI 輔助故障診斷，致力於建構台灣自主研發與產業化實力。

圖一：電動輔助自行車輪轂電機系統整合開發開發團隊

跨域合作與創新研發

研究團隊以多年技術累積，積極投入微型與高速電機、車用動力系統及永磁同步馬達驅動器等關鍵領域，並與產業、國防及太空單位合作，推動多項具策略性的研發計畫。

在太空科技方面，團隊攜手國家太空中心與公準精密公司，成功研製商用規格之高效能「反應輪」裝置，此為衛星姿態控制核心元件，預計未來搭載於國產衛星，實現國產化關鍵里程碑。

於電動車領域，與中鋼公司合作研發之 100kW 級馬達已完成實車測試，性能與國際水準相當。團隊亦率先導入碳化矽驅動器與馬達 / 驅動器整合設計，為國內少數掌握該核心技術之團隊，奠定電動車產業升級基礎。

在 AI 進行故障預測與診斷，藉由相關成果的發表，已獲得國際重視，並因此獲選為 IEEE Magnetics Society Distinguished Lecturer。

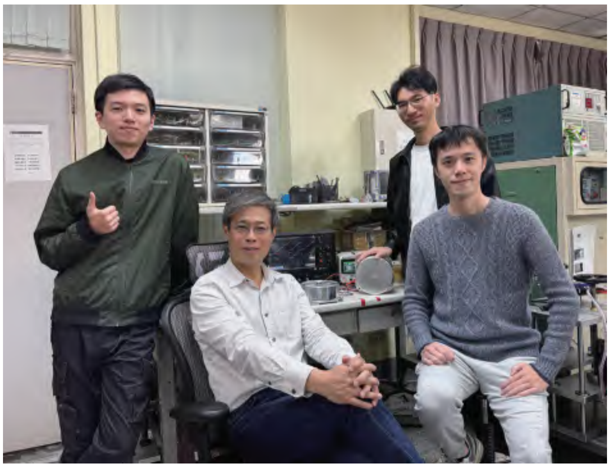
成果與肯定

團隊研究成果獲學術界與產業界高度肯定。本人獲頒中國工程師學會傑出工程教授獎、李國鼎科技與人文講座金質獎、國防先進科技優質計畫獎與國科會傑出研究獎等。學生團隊亦曾榮獲科技部創新創業激勵計畫首獎，創立新創公司「張量科技」，所開發球型馬達成功搭載衛星實測，顯示青年創新動能與技術轉化潛力。

而配合新南向政策，團隊亦積極培育國際學生，部分畢業生已返國任教或進入產業發展，亦有學生選擇留台，為本地科研注入多元化與國際化能量。

未來展望：打造更堅韌的台灣科技鏈

展望未來，團隊將持續強化電機與驅動系統技術，擴展至通訊衛星、電動飛行載具等應用場域。藉由深化產學合作與國際鏈結，



圖二：國家太空中心與公準精密公司，成功研製商用規格之高效能「反應輪」裝置

推動研究成果轉譯與人才培育，建立自主、韌性兼具的台灣科技生態系。

結語：從地下實驗室到太空實測

從早期實驗室拆解「轉不動」的球型馬達、成立新創公司到成功將國產技術送上太空，這段歷程不僅展現研究成果的落實，更彰顯青年創業與跨域研究的精神。相信跨域研究是科技創新與突破的重要因素。

Cross-Disciplinary Innovation: Electric Vehicles, Space Technology, and AI Applications

Min-Fu Hsieh, Distinguished Professor
College of Electrical Engineering and Computer Science, Department of Electrical Engineering

Distinguished Professor Min-Fu Hsieh of the Department of Electrical Engineering at National Cheng Kung University leads the Electrical Machine and Drive System Laboratory and previously served as Deputy Vice President for Research and Development. His expertise focuses on high-performance electric machine design and intelligent drive systems. In recent years, he has led multiple projects involving wide bandgap power device applications in high-performance motor drives, high power-density servo motors, and AI-based intelligent fault diagnosis algorithms. Through collaborations with industry partners, he has promoted the localization of key technologies such as high-power electric vehicle motors and satellite reaction wheels, thereby enhancing Taiwan's R&D capabilities in electric mobility and space technology. Professor Hsieh has also been deeply involved in IEEE international conferences and journal editorial work, actively building international linkages and dedicating himself to cultivating globally competitive high-level talent.

Our team focuses on motor design and drive control, electric vehicle systems, satellite attitude control, and AI-based fault diagnosis, aiming to advance Taiwan's technological self-reliance and cultivate high-level research talent. We have collaborated with China Steel Corporation to develop high-performance electric vehicle motors and with the National Space Organization to produce domestically made reaction wheels. Our achievements in AI-assisted diagnostics have also been internationally recognized.

From Space to Ground: The Unfinished Dream of Technology

With the rapid advancement of the space industry, electric vehicles, and national defense autonomy, Taiwan, despite its solid industrial foundation, still heavily relies on international suppliers for critical technologies and core components—resulting in high costs and potential technological gaps. In pursuit of the goal of "technological self-reliance," our research team has long been dedicated to the development of high-performance electric

圖一：電動輔助自行車輪轂電機系統整合開發開發團隊

machines and motor drive technologies. Our work spans motor design, vehicle power systems, drive control, and AI-assisted fault diagnosis, aiming to establish Taiwan's capabilities in independent R&D and industrialization.

Cross-Disciplinary Collaboration and Innovative Research

Leveraging years of accumulated expertise, the research team actively engages in strategic R&D initiatives across key domains such as miniature and high-speed electric machines, vehicle propulsion systems, and permanent magnet synchronous motor (PMSM) drives. These efforts are conducted in close collaboration with industry, defense, and space organizations.

In the field of space technology, the team partnered with the National Space Organization (NSPO) and Gong Zhun Precision Co. to successfully develop a commercially viable, high-performance reaction wheel—a core component for satellite attitude control. This development marks a critical milestone toward the localization of key satellite subsystems and is slated for future deployment on domestically produced satellites.

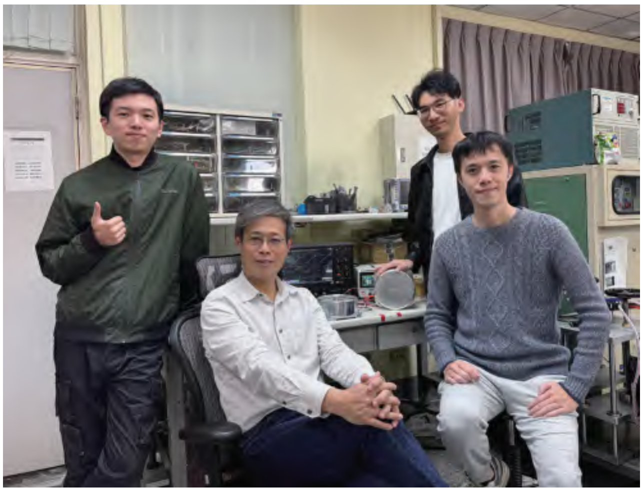
In the electric vehicle sector, the team collaborated with China Steel Corporation to develop a 100 kW-class traction motor, which has successfully completed real-vehicle testing, demonstrating performance on par with international standards. Furthermore, the team is among the few in Taiwan to implement silicon carbide (SiC) drive technology and integrated motor/drive system design, laying a solid foundation for the advancement of the domestic EV industry.

In the area of AI-based fault prediction and diagnosis, the team's published research has garnered significant international attention, earning the distinction of IEEE Magnetics Society Distinguished Lecturer for its contributions.

Achievements and Recognition

The team's research outcomes have received widespread recognition from both academia and industry. The principal investigator has been honored with several prestigious awards, including the Outstanding Engineering Professor Award from the Chinese Institute of Engineers, the Lee Kuo-Ding Gold Medal for Science, Technology and Humanities, the Excellence in Defense Advanced Technology Project Award, and the Outstanding Research Award from the National Science and Technology Council (NSTC).

The student team also received first prize in the NSTC Innovation and Entrepreneurship



圖二：國家太空中心與公準精密公司，成功研製商用規格之高效能「反應輪」裝置

Incentive Program, subsequently founding a startup company, Tensor Tech, which successfully developed a spherical motor tested in orbit aboard a satellite—demonstrating both youth-led innovation and the potential for effective technology transfer.

In alignment with the New Southbound Policy, the team actively cultivates international talent. Several international graduates have returned to their home countries to pursue academic or industrial careers, while others have chosen to remain in Taiwan, contributing to the diversification and internationalization of the local research ecosystem.

Future Outlook: Building a More Resilient Taiwanese Technology Ecosystem

Looking ahead, the team will continue to strengthen technologies in electric machines and drive systems, extending their applications to areas such as communication satellites and electric aerial vehicles. Through deepening academia-industry collaboration and international partnerships, the team aims to accelerate research translation and talent cultivation, contributing to the development of a self-reliant and resilient technology ecosystem in Taiwan.

Conclusion: From Basement Labs to In-Orbit Validation

From dismantling an early-stage, non-functional spherical motor in a laboratory, to founding a startup, and ultimately sending domestically developed technology into space, this journey not only demonstrates the realization of research outcomes but also embodies the spirit of youth entrepreneurship and interdisciplinary collaboration. We believe that cross-disciplinary research is a vital driver of technological innovation and breakthrough.

國科會
傑出特約研究員

NSTC
Distinguished Research Fellow Award

論生成式人工智慧在教育之最終目標：高層次思維與反思思維

The Ultimate Goal of Generative AI in Education: Higher-Order Thinking and Reflective Thinking

論生成式人工智慧在教育之最終目標：高層次思維與反思思維

—— 黃悅民，講座教授
工學院 / 工程科學系

黃悅民教授現任工程科學系講座教授，主要研究領域為資訊技術在 STEM 教育中的應用，近年特別聚焦於生成式人工智慧（GAI）之發展與實踐，並已有兩篇相關論文榮獲 2024 年「高被引論文」殊榮。黃教授於今年亦獲國科會頒發「傑出特約研究人員獎」，其所指導之博士畢業生亦屢獲殊榮，包括「傑出獎」與多位「吳大猷獎」得主。

值得一提的是，黃教授為國際知名會議 ICITL（International Conference on Information Technology in Learning）的創辦人。該會議長期獲 Springer 出版社支持，每年吸引約 30 個國家參與，已成為我國與歐洲在教育科技領域交流與合作的重要橋樑。

生成式人工智慧正快速重塑教育場域，從課程設計、學習輔助到思維訓練皆帶來嶄新改變。其核心價值不應僅止於提升知識獲取效率，更應致力於培養學生具備高層次思維與反思思維能力，進而推動更深層次的理解、批判性思考與自主學習的轉化歷程。

隨著 ChatGPT 等生成式人工智慧（Generative AI, GAI）工具在教育領域的應用日益廣泛，許多教師與學生開始嘗試將其納入教學與學習流程中。然而，在這場 AI 熱潮中，我們更應深思：教育的最終目標是什麼？我們不能將 AI 僅視為加快資訊傳遞或作業自動化的工具，更應思考它是否真正有助於培養學生「會思考」「會創造」的能力。特別是在 STEM 教育中，學習早已不再是單向的知識接收，而是透過探究、協作與反思，發展學生面對複雜問題所需的高層次思維能力。

GAI 的發展，特別是大型語言模型如 ChatGPT 的問世，顛覆了傳統教育的教學方式與學習樣貌。AI 工具不再只是資訊搜尋的輔助器，而成為學生的對話夥伴、知識建構的引導者，甚至能參與學習歷程中的反思與評估。過去教師常面臨的挑戰，如學生難以釐清問題本質、缺乏高層次思維訓練，或在複雜任務中無法有效反思自身表現，如今透

過生成式 AI 的輔助，已有突破的可能。

在本團隊系列研究中，我們嘗試結合生成式 AI 於 STEM 教育場域，開發了多項創新學習工具，包括 GPT 輔助摘要工具（GASA）[1]、InquiryGPT 引導系統 [2]、PA-GPT 同儕互評機制 [3]、GCLA 引導式學習架構 [4]，以及 GPT Feedback System（GPTFS）[5] 等。這些工具的設計宗旨並非讓 AI「給答案」，而是透過提示、對話與引導設計，促進學生的提問能力與批判思維。學生在動手實作、概念建構與小組討論等學習活動中，透過 AI 回饋重新思考原有認知，逐步培養反思思維與高層次的問題解決能力。這樣的歷程不僅有助於知識內化，更提供了一個結合科技與深度學習的實踐場域 [6]。

從教育的本質來看，「高層次思維」（Higher-Order Thinking, HOT）培育強調透過記憶、理解、應用、分析以進一步具備評估、分析與創造的能力；「反思思維」（Reflective Thinking）則強調學生能夠自我檢視學習歷程與經驗，理解學習策略的有效性與自我成長的空間 [7]。兩者皆是 21 世紀學習者不可或缺的能力。然而，這些能力的培養需長時間累積、需經歷挫折與自我調整，也正是傳統教育中最難以全面落實之處。

而生成式 AI 的介入，為這些教育困境開啟了轉機。學生可在沒有壓力的情境下與 AI 互動，嘗試各種解題策略，接受即時回饋，甚至重新檢視先前的思路。當 AI 提供的是「引導與提示」而非「答案與結論」，學生將逐步養成主動思考與自我修正的學習習慣 [8]。這樣的學習歷程，正是反思思維與高層次認知發展的關鍵。

此外，教師的角色也逐漸從單純的知識傳授者，轉變為學習歷程中的引導者與思考促進者 [9]。面對生成式 AI 的快速發展，教師更需要有意識地設計能引發學生反思、提問與遷移能力的學習活動，並在學生與 AI 互動過程中提供適切的回饋與判斷，協助學生理解與內化學習內容。透過人與 AI 的協同互動，教師不僅引導學生善用 AI 工具作為學習夥伴，更確保 AI 干預能對學習歷程產生積極與深刻的影響。

綜上所述，GAI 的教育應用，應以促進學生的高層次思維與反思思維為核心價值。我們應跳脫 AI 只是「答案生成工具」的刻板印象，轉而思考它如何引導學生思考、如何成為學習歷程的夥伴。這樣的視角不僅讓科技與教育真正融合，更是通往深度學習與自主成長的關鍵途徑。

生成式 AI 的教育價值，並不在於產生完美答案，而在於啟發學生提出問題、檢視觀點、探索解方的能力。從各項實證研究中可看出，當 AI 作為教學輔助夥伴，結合引導機制與多模態回饋，更能啟動學生的深度學習歷程。

未來生成式 AI 的應用，將不侷限於答題與輔導，更可能進化為學習歷程中的「認知鏡子」，幫助學生持續自我反思與調整學習策略。同時，我們也需思考如何發展公平、可解釋、具倫理的 AI 教學工具，確保其在教育場域中的長遠發展與信任基礎。

當教育與 AI 相遇，真正值得追求的，不是取代教師或簡化學習，而是透過科技的協助，讓每位學生都能思考更深、反思更廣，邁向更高層次的學習未來。

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學生於 STEM 課程中透過實作與筆電操作，進行與生成式 AI 相關的學習任務與反思活動。

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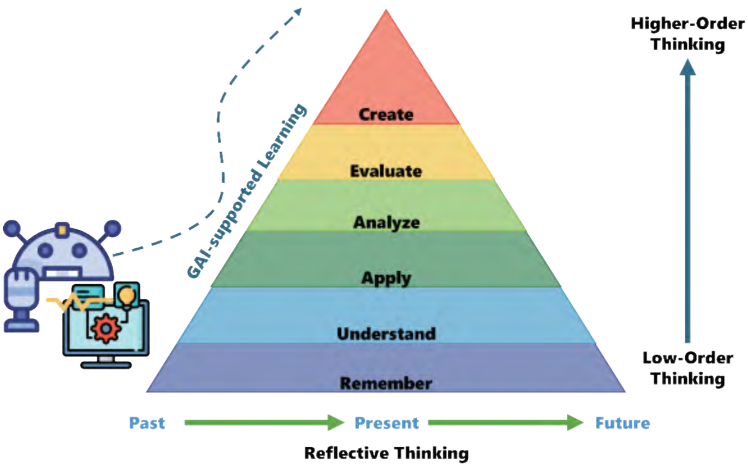

生成式 AI 工具如 GPT 輔助摘要工具（GASA）、InquiryGPT 引導系統、PA-GPT 同儕互評機制、GCLA 引導式學習架構，以及 GPT Feedback System（GPTFS）能夠在認知建構層級中提供支持，從理解與應用到創造與反思，協助學生發展更深層的學習能力。

The Ultimate Goal of Generative AI in Education: Higher-Order Thinking and Reflective Thinking

Yueh-Min Huang, Chair Professor
College of Engineering,
Department of Engineering Science

Professor Yueh-Min Huang is currently a Chair Professor in the Department of Engineering Science. His primary research focuses on the integration of information technology into STEM education, with recent emphasis on the application of Generative AI (GAI). He has published two papers on this topic that have been recognized as 2024 Highly Cited Papers.

In 2024, Professor Huang was honored with the Merit NSTC Research Fellow Award by the National Science and Technology Council (NSTC). Notably, Professor Huang is the founder of the internationally renowned ICITL (International Conference on Information Technology in Learning). Supported by Springer, this conference attracts participants from around 30 countries each year and has become a key platform fostering collaboration between Taiwan and Europe in the field of educational technology.

Generative AI is rapidly transforming the landscape of education. Its true value goes beyond enhancing knowledge acquisition—it aims to cultivate students' higher-order thinking and reflective thinking skills. By doing so, it fosters deeper understanding, critical learning processes, and more meaningful engagement, aligning with the ultimate goals of education in the era of intelligent technology.

As generative AI tools like ChatGPT become increasingly prevalent in education, educators and students alike are integrating them into teaching and learning. Yet amid this AI boom, we must reconsider a fundamental question: what is the true goal of education empowered by AI? AI should not be seen merely as a tool for accelerating information access or automating assignments. Instead, it should help cultivate students' abilities to think critically, reflect deeply, and create meaningfully. In STEM education especially, learning has shifted from passive knowledge intake to active inquiry, collaboration, and reflection—skills essential for developing higher-order thinking and solving complex, real-world problems.

The emergence of generative AI—especially large language models like ChatGPT—is redefining the way education is delivered and experienced. These tools are no longer mere search engines or automated writing tools; they have evolved into interactive partners capable of guiding inquiry, prompting reflection, and supporting critical thinking throughout the learning journey.

In our series of studies, we integrated generative AI into various STEM education settings and developed a range of innovative learning tools, including the GPT-Assisted Summarization Aid (GASA) [1], InquiryGPT [2], the peer assessment framework PA-GPT [3], the guided ChatGPT Learning Aid (GCLA) [4], and the GPT Feedback System (GPTFS) [5]. The central goal of these tools is not to provide direct answers, but to support students through prompts, dialogue, and structured guidance that enhance their inquiry and critical thinking. Across activities such as hands-on tasks, conceptual exploration, and collaborative learning, students engaged with AI feedback to reassess prior understanding, fostering reflective thinking and higher-order problem-solving skills. These experiences not only support knowledge construction, but also create authentic learning environments where technology and deep learning coalesce [6].

From a pedagogical perspective, higher-order thinking (HOTS) includes the skills of application, analysis, evaluation, and creativity. Reflective thinking, meanwhile, involves learners evaluating their learning processes and making informed adjustments [7]. These skills are critical to preparing learners for the complexities of the 21st century, yet they are often underdeveloped in traditional, teacher-centered classrooms.

Generative AI offers a promising remedy. It provides a space for students to explore, fail safely, and try again—receiving immediate, formative guidance from AI without judgment. When AI acts as a guide rather than a solution-provider, learners are encouraged to engage more deeply and reflectively, fostering a habit of metacognitive thinking and continuous improvement [8].

Importantly, the role of the teacher remains indispensable. Rather than becoming mere designers or AI facilitators, teachers continue to serve as essential guides and thinking partners throughout the learning process [9]. They provide timely feedback, pose critical questions, and help students interpret and internalize AI-generated content. By facilitating meaningful interactions between students and AI, teachers ensure that technology enhances—not replaces—human-centered learning, and that students develop their thinking with depth, autonomy, and purpose.

In conclusion, the integration of generative AI in education must aim higher than efficiency. It must strive to cultivate learners' ability to think critically, reflect deeply, and learn independently. When used thoughtfully, AI becomes more than a tool—it becomes a catalyst for educational transformation aligned with the true purposes of learning.

The true educational value of generative

AI lies not in generating perfect answers, but in inspiring learners to ask questions, challenge perspectives, and explore solutions. Empirical evidence suggests that when AI is used as a guided learning aid, with multimodal feedback and scaffolding, it effectively triggers students' deep learning processes.

The future of generative AI in education extends beyond answering questions—it may become a "cognitive mirror" that supports continuous self-reflection and adaptive learning strategies. At the same time, it is crucial to develop fair, explainable, and ethical AI learning tools to ensure sustainable and trustworthy integration in educational settings.

When education meets AI, the true pursuit is not to replace teachers or simplify learning, but to use technology to help every learner think deeper, reflect further, and reach a higher level of intellectual growth.

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Students engaged in STEM learning tasks involving hands-on activities and reflective thinking with generative AI support.

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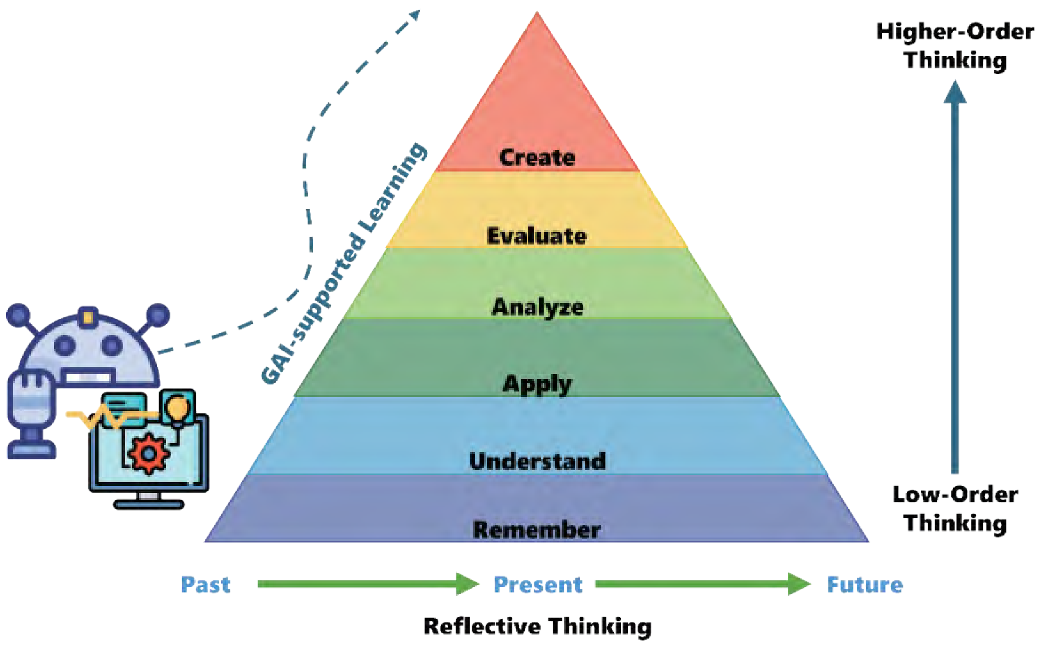

Generative AI tools—such as the GPT-Assisted Summarization Aid (GASA), InquiryGPT, the peer assessment system PA-GPT, the guided learning framework GCLA, and the GPT Feedback System (GPTFS)—support students across different cognitive levels in Bloom's Taxonomy, from understanding and applying concepts to analyzing, creating, and engaging in reflective thinking. These tools foster deeper, more meaningful learning.

國科會
吳大猷先生紀念獎

NSTC
Mr. Wu Ta-You Memorial Award

透過自然對流分析不規則粗糙表面，設計高效能散熱鰭片

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透過自然對流分析不規則粗糙表面，設計高效能散熱鰭片

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李崇綱博士目前為國立成功大學機械工程學系副教授，同時擔任日本神戶大學與九州大學的客座副教授，以及台灣太空中心兼任顧問。

李博士於 2011 年在國立交通大學取得工程博士學位，指導教授為傅武雄教授。

博士畢業後，於 2012 年加入日本理化學研究所先進計算科學研究中心（RIKEN R-CCS），在坪倉誠教授的研究團隊擔任博士後研究員。

2016 年，他成為神戶大學專案助理教授，也同時為 RIKEN R-CCS 的訪問研究員。

2018 年晉升為神戶大學終身聘講師，並於 2022 年回到台灣成功大學擔任副教授。

李博士的研究興趣包括：高溫差自然對流、可壓縮流數值求解、計算氣動聲學、紊流模型建構，超級電腦運算與大規模模擬等。

本研究探討在自然對流條件下，具有不規則粗糙表面的垂直鰭片如何影響散熱效率。透過模擬分析，我們發現適度的表面粗糙度有助於提升熱傳效果，但過度粗糙反而會降低效率。此外，表面結構的排列方式對空氣流動影響顯著，進而改變散熱表現。研究結果指出，設計有效的散熱鰭片，應注重表面形狀與流動行為的互動，而非僅追求表面積的增加。

隨著電子元件體積越來越小、功率密度越來越高，如何有效散熱成為一大挑戰。自然對流是一種不需要風扇、靠空氣自身流動來帶走熱量的被動式散熱方式，因其簡單、低成本，越來越受到關注。本研究聚焦於不同粗糙度表面在自然對流下的散熱行為，並進一步設計出能有效提升散熱效率的鰭片幾何形狀。

在研究中 [1]，我們針對具有隨機粗糙度的垂直平板進行模擬分析（圖 1）。由於此類問題涉及低速空氣流動與複雜幾何結構，我們採用自行開發的計算流體力學（CFD）工具，並透過國網中心的超級電腦進行高效能運算。為全面比較光滑與粗糙表面的優劣，我們分析了各種粗糙程度下的平均努塞爾數（Nu，一種衡量熱從固體表面傳至周圍空氣

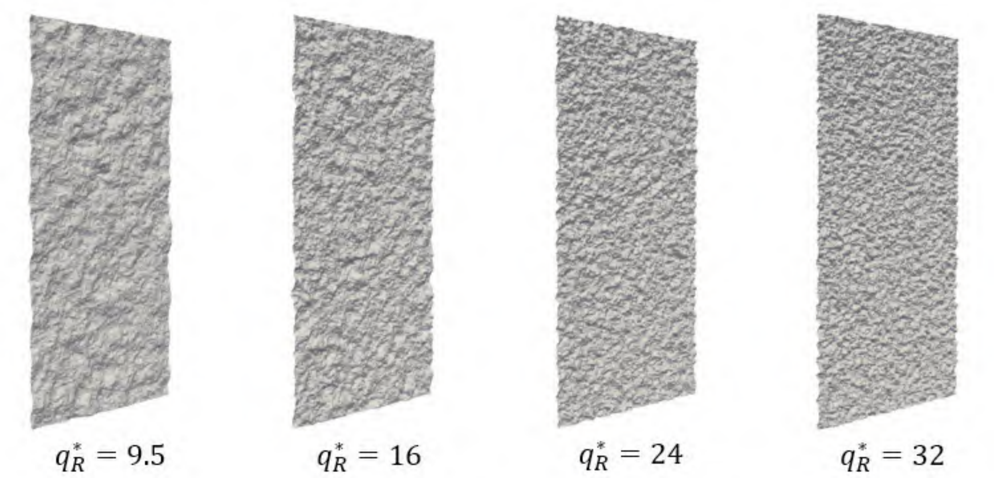

圖 1 不同隨機粗糙程度之表面 (經許可轉載自 [1])

表 1 不同粗糙表面之平均 Nu 比較

q_R^*	Nu	Difference (%)
Smooth	27.85	-
9.5	32.80	+17.75
16	30.046	+7.87
24	24.47	+2.2
32	27.32	-1.92

效率的指標，數值越高表示散熱越好）。根據表 1 的結果顯示，除了最粗糙的表面外，大多數粗糙表面的平均 Nu 值都高於光滑平板，其中最高者提升達 17.75%，但是當粗糙度變高時，效率反而呈現下降的趨勢。從速度場分析 (圖 2) 可以發現，在靠近入口的上游區域，粗糙表面的流速普遍低於光滑表面；但在中游與下游區域，部分粗糙表面反而表現更佳。這一趨勢也反映在圖 3 所示的 Nu 分佈圖中，顯示粗糙元素的排列方式對散熱效果有明顯影響，特別在中游區域最為敏感。值得注意的是，過去人們普遍認為表面越粗糙散熱效果越好，但我們的模擬結果卻呈現相反的趨勢。從不同方向的速度場分析（圖 4）中可見：在圖 4a 中，凹陷處呈現藍色，代表流速接近 0，空氣被困在凹槽中；而圖 4b 顯示，當粗糙度增加，凸起附近的左右流動被削弱，表示空氣在爬坡與下坡時流速更慢，使其更難將熱量帶離表面，最終導致整體散熱效率下降。

根據本研究分析結果，我們提出三項設計建議，以提升自然對流下的散熱效率：

1. 避免使用尖銳的粗糙結構，以免減少有效散熱面積。
2. 避免高頻率的粗糙排列，防止削弱凸起處後方的空氣循環。
3. 減少凹陷深度，降低高速流動時的熱量堆積效應。

本研究顯示，在自然對流下，表面的幾何形狀與粗糙度對散熱效率有關鍵影響。

雖然適度的粗糙度有助於提升熱傳效果，但過度粗糙反而會造成空氣滯留、降低散熱效率。此外，我們也發現，表面形狀的設計不應只追求面積的增加，更重要的是如何讓空氣有效流動並帶走熱量。這些結果強調了在自然對流散熱設計中，表面結構的合理佈局比單純擴大表面積更為關鍵。未來我們將持續探索不同表面結構與幾何參數對自然對流效能的影響，目標是建立一套可用於小型電子設備的最適化幾何設計策略，提供高效、低噪音且可靠的被動散熱方案。更長遠來看，此類不規則表面設計的原理，也有潛力應用於太陽能集熱器、建築通風系統，甚至是太空船的熱控裝置等熱管理相關領域。在這些應用中，即使是微小的效率提升，都可能帶來顯著效能改善，而表面設計，正是其中的關鍵突破點。

期刊論文

[1] Tse-Yu Chen, ChungGang Li*, The impact of random 3D roughness on natural convection along a vertical plate, Int. Commun. Heat Mass. 154 (2024) 107433

[2] ChungGang Li*, R Bale, WH Wang, M Tsubokura, A sharp interface immersed boundary method for thin-walled geometries in viscous compressible flows, Int. J. Mech. Sci. 253 (2023) 10841

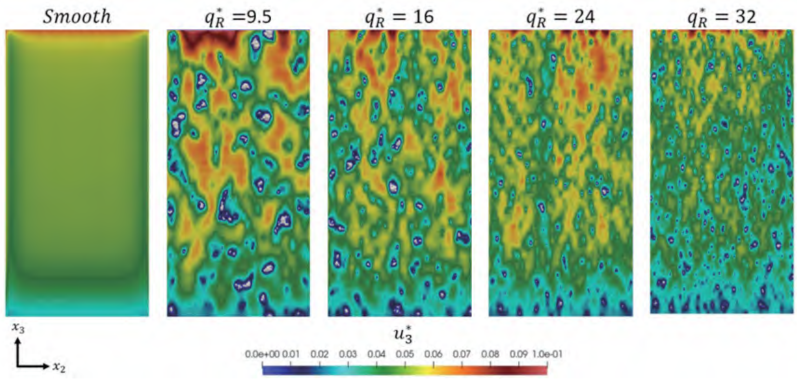

圖 2 不同粗糙表面之速度截面分布 (經許可轉載自 [1])

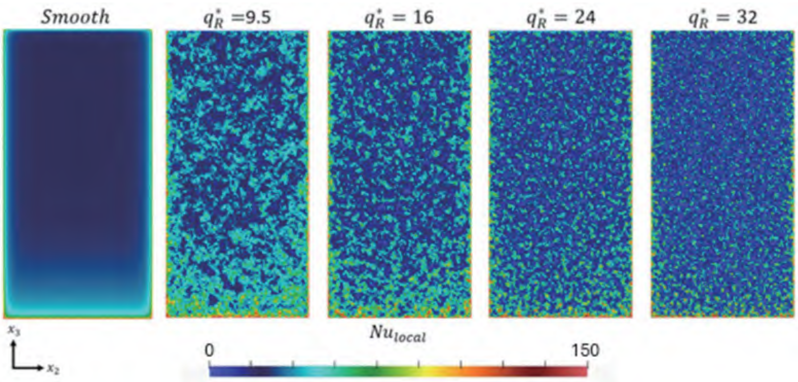

圖 3 不同粗糙表面上之 Nu 分布 (經許可轉載自 [1])

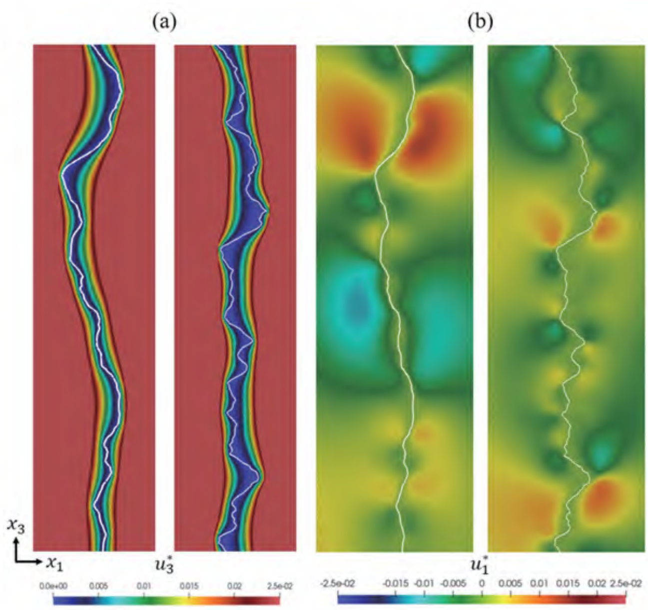

圖 4 (a) 平行 (b) 垂直 於主流方向之局部速度分布 (經許可轉載自 [1])

Designing Efficient Heat Dissipation Fins Through Natural Convection Analysis of Irregular Rough Surfaces

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College of Engineering, Deparment of Mechanical Engineering

Dr. ChungGang Li is an Associate Professor in the Department of Mechanical Engineering at National Cheng Kung University, Taiwan. He also serves as an Invited Associate Professor of Computational Science at Kobe University, Japan, and as an Adjunct Consultant at the Taiwan Space Agency.

Dr. Li earned his Ph.D. in Engineering from National Chiao Tung University, Taiwan, in 2011, under the supervision of Professor Wu-Shung Fu. Following the completion of his doctorate, he joined the research group of Professor Tsubokura at the RIKEN Advanced Institute for Computational Science as a postdoctoral researcher in 2012. In 2016, he became a Project Assistant Professor at Kobe University and was also appointed as a visiting researcher at the RIKEN Center for Computational Science. In 2018, he was promoted to Associate Professor at Kobe University. Additionally, he has been a visiting scholar at the University of Southern California.

Dr. Li's research interests include natural convection with high temperature differences, compressible flow solvers, computational aeroacoustics, turbulence modeling, and large-scale simulations on supercomputers.

This study investigates how vertical fins with irregular rough surfaces affect heat dissipation efficiency under natural convection. Through simulation analysis, we found that moderate surface roughness improves heat transfer, while excessive roughness reduces efficiency. The arrangement of surface structures significantly influences airflow, thereby altering thermal performance. Our findings suggest that effective fin design should focus on the interaction between surface geometry and flow behavior, rather than simply increasing surface area.

As electronic components continue to shrink while generating more heat, effective thermal management has become an increasingly pressing challenge. Natural convection, a passive cooling method that relies on air moving naturally without the need for fans or pumps, is gaining attention due to its simplicity and low cost. This study focuses on how different surface roughness

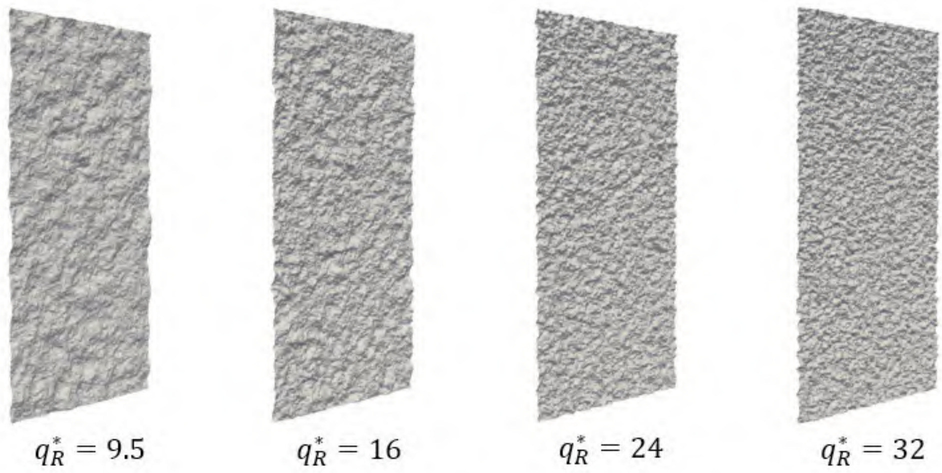

Fig. 1 Surfaces with Different Degrees of Random Roughness

Table 1 Average Nu for Different Conditions

q_R^*	Nu	Difference (%)
Smooth	27.85	-
9.5	32.80	+17.75
16	30.046	+7.87
24	24.47	+2.2
32	27.32	-1.92

levels influence heat dissipation under natural convection and further proposes optimized fin geometries to enhance thermal performance.

In the initial phase [1], we conducted simulations on vertical plates with randomly distributed surface roughness (Fig. 1). Since this problem involves low-speed airflow and complex surface geometries, we utilized a customized computational fluid dynamics (CFD) tool developed by the authors [2] and executed the simulations on the supercomputers at the National Center for High-Performance Computing. To thoroughly compare the performance of smooth versus rough surfaces, we analyzed the average Nusselt number (Nu, a dimensionless number that indicates how efficiently heat is transferred from a surface to the surrounding air). A higher Nu means better heat dissipation. Except for the roughest cases, most rough surfaces achieved higher Nu values than the smooth plate, with the best case showing a 17.75% improvement. However, when roughness became too extreme, efficiency declined. Velocity field analysis revealed that in the upstream region near the inlet, rough surfaces generally experienced lower flow speeds than smooth ones. However, in the midstream and downstream regions, some rough surfaces outperformed the smooth plate. This trend is echoed in the Nusselt number distribution (Fig. 3), highlighting that the arrangement of roughness elements significantly influences heat transfer, especially in the midstream zone. Interestingly, while it's commonly believed that increased surface roughness improves cooling, our results showed the opposite trend at high roughness. From the velocity fields in Fig. 2, we observed that in Fig. 2a, fluid velocity in the valleys dropped to near zero (blue regions), meaning air became trapped. In Fig. 2b, the lateral flow near the peaks weakened with increasing roughness, making it harder for air to "climb" and "descend" the surface features. This reduced airflow increased heat retention and lowered overall thermal performance. Based on our findings, we propose three design guidelines for improving natural convection heat transfer:

1. Avoid sharp roughness elements to prevent reducing the effective heat dissipation area.

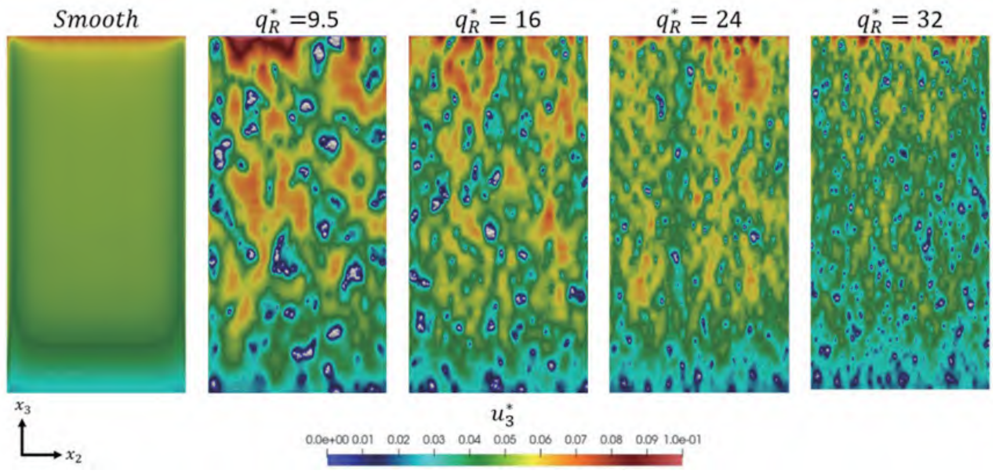

Fig. 2 Velocity distribution on different surface

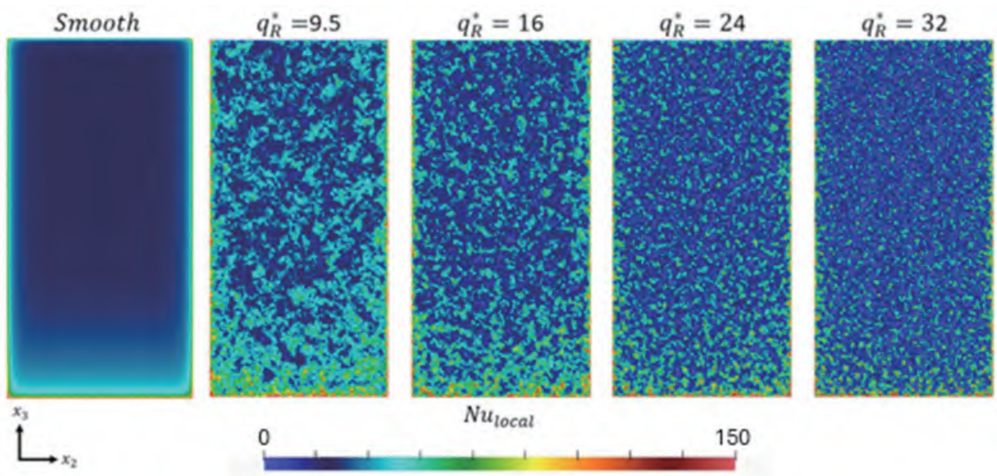

Fig. 3 Local Nusselt Number Distribution

2. Avoid high-frequency roughness patterns, which weaken recirculation behind peaks.

3. Reduce valley depth to prevent heat accumulation when flow velocity increases.

This study demonstrates that surface geometry and roughness play a critical role in heat dissipation under natural convection. While moderate roughness can enhance heat transfer, excessive roughness may trap air and reduce cooling efficiency. Moreover, our findings show that effective surface design is not just about increasing area—it's about facilitating airflow to carry heat away. These results highlight that strategic surface structuring is more crucial than surface area alone in natural convection cooling design. Looking ahead, we plan to further investigate how different surface geometries affect natural convection, with the goal of developing optimal design rules for passive cooling of compact electronic devices. In the long term, these principles could also be applied to broader fields such as solar thermal collectors, building ventilation, or spacecraft thermal control systems. In all these cases, even small gains in thermal efficiency can lead to meaningful performance improvements—and surface design could be the key to unlocking them.

Reference

[1] Tse-Yu Chen, ChungGang Li*, The impact of random 3D roughness on natural convection along a vertical plate, Int. Commun. Heat Mass. 154 (2024) 107433

[2] ChungGang Li*, R Bale, WH Wang, M Tsubokura, A sharp interface immersed boundary method for thin-walled geometries in viscous compressible flows, Int. J. Mech. Sci. 253 (2023) 10841

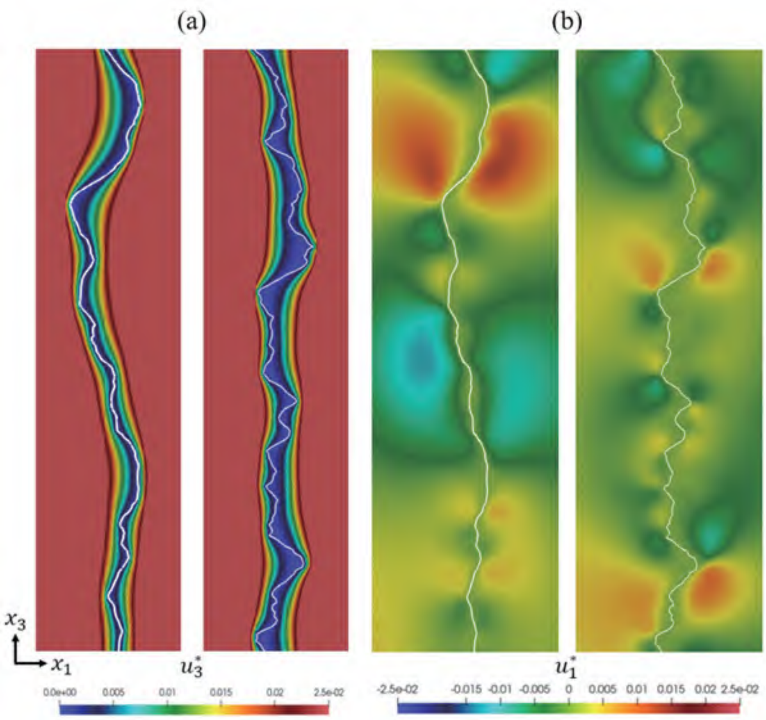

Fig. 4 (a) Parallel (b) Perpendicular Velocity Distributions Relative to the Mainstream Direction

從預測到決策：延遲出院老年病患之長期照護安置最佳化

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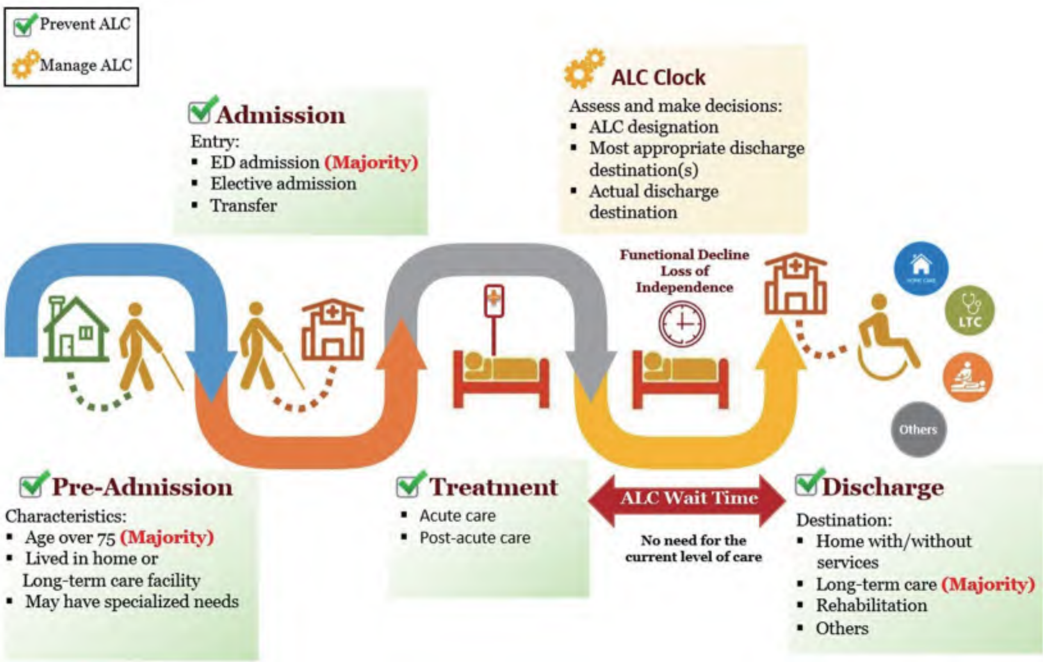
莊雅棠現為國立成功大學工業與資訊管理學系副教授，畢業於加拿大多倫多大學工業工程學系。自民國 109 年 8 月 1 日起加入成功大學工業與資訊管理學系任教。其主要研究領域為隨機最佳化模型在實務中的應用，涵蓋庫存管理、機台維修決策最佳化及醫療管理等。

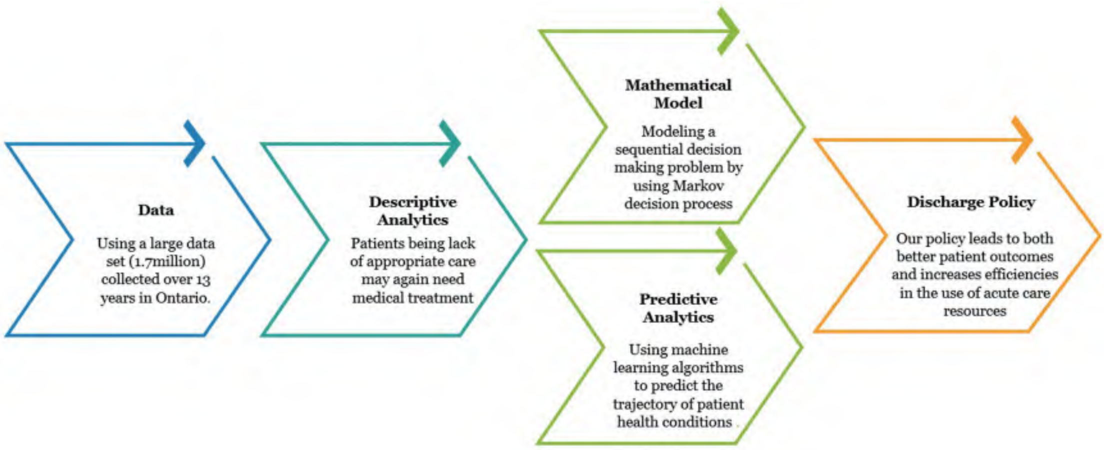
隨著老年人口迅速增加，醫療機構中延遲出院病患的比例不斷上升，造成醫療資源的嚴重壓力。本研究針對此挑戰，提出一套融合機器學習與馬可夫決策程序的創新模型，能夠根據病患的健康狀態預測其未來病程，並根據此預測結果做出個人化的長照安置決策。透過長達 13 年的實際醫療資料進行模型的訓練，本模型不僅能減少醫院成本與住院時間，更能優化長照床位的使用效率，對未來高齡化社會的醫療政策規劃具有重要啟示。

隨著人口高齡化，醫院中延遲出院的老年病患數量迅速上升，對醫療系統造成巨大壓力。這些病患已不再需要醫院病床，但因長期照護資源不足，無法出院。這些病人佔據醫院病床，導致急診壅塞與手術延期，甚至影響整體醫療品質。傳統出院相關決策常仰賴臨床經驗，難以因應病患健康狀況的多樣性與複雜性，本研究根據不同症狀的病人提供個人化的出院建議。

本研究由臺灣成功大學與加拿大多所研究機構合作，提出一套創新的「預測驅動式決策模型」，以個別病患的健康狀態與特徵，預測其未來病程，並透過馬可夫決策程序（MDP）設計最適出院策略。研究團隊使



延遲病患的形成



模型架構

用橫跨 13 年的歷史資料，涵蓋超過 16 萬名加拿大安大略省的老年病患，建立個人化的健康轉移模型與成本估算函數。透過指標式政策（Index Policy）進行決策，能在不同病患間有效排序出院優先順序。數值實驗顯示，此模型可有效降低醫療成本，並減少病患住院時間。

本研究證明，將機器學習預測資訊納入出院決策，可大幅提升醫療資源使用效率，減少住院時間與成本，並緩解長照床位不足問題。

本模型具高度可擴展性，可應用於其他地區或病患族群，未來也可整合即時資料與電子病歷進行動態調整。此方法亦可拓展至

其他醫療資源分配問題，如手術排程或加護病房管理。

在資源有限且人口老化持續加劇的情況下，如何有效管理 ALC 病患，已成為全球醫療體系的關鍵挑戰。結合 AI 與作業研究的決策工具，為解決此問題提供了新契機。

期刊論文

Chuang, Y. T., M. Zargoush, S. Ghazalbash, S. Samiedaluie, K. Kuluski, S. Guilcher. 2023. From prediction to decision: Optimizing long-term care placements among older delayed discharge patients. Production and Operations Management, 32 (4), 1041-1058.

From Prediction to Decision: Optimizing Long-Term Care Placements for Older Delayed Discharge Patients

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With the rapid growth of the aging population, the proportion of Alternate Level of Care (ALC) patients in hospitals is steadily rising, causing significant strain on healthcare resources. This study addresses the challenge by proposing an innovative model that integrates machine learning with a Markov decision process (MDP) to predict individual patient trajectories and optimize their long-term care (LTC) placement. Trained and tested on 13 years of real-world healthcare data, the model is shown to effectively reduce hospital costs and lengths of stay while improving the efficiency of LTC bed utilization, offering valuable insights for future aging-related healthcare policies.

With population aging, the number of older patients experiencing delayed discharge (designated as Alternate Level of Care, or ALC) is rapidly increasing, placing immense pressure on healthcare systems. These patients no longer require acute care but remain in hospitals due to limited

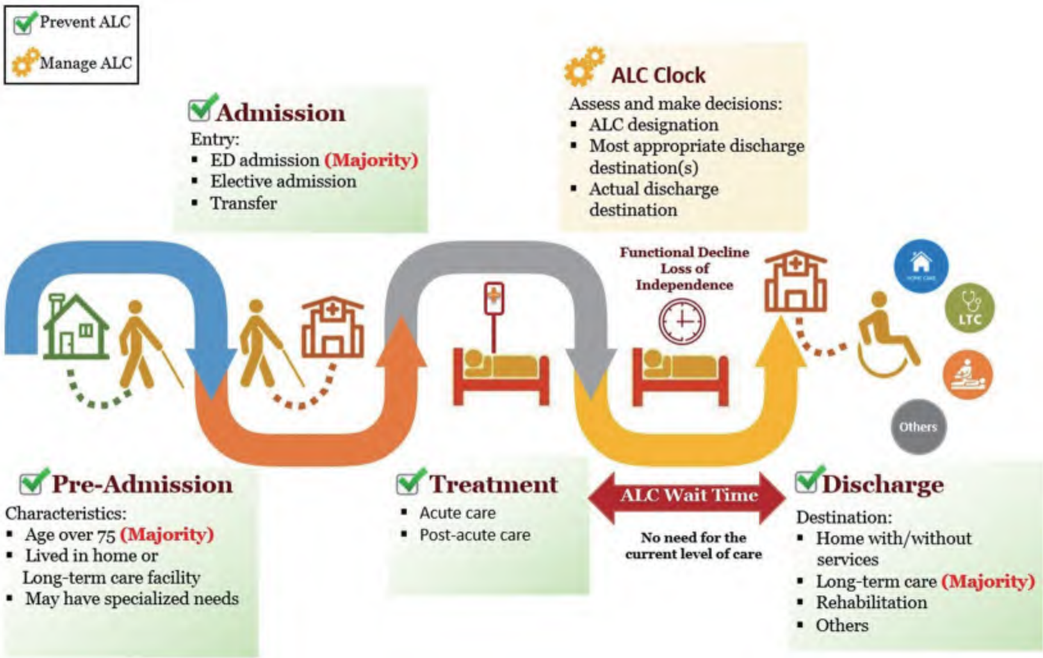

Figure: detailed picture of the ALC patient journey.

LTC resources, causing bed shortages, emergency department congestion, and canceled procedures. Traditional discharge planning is often based on clinical judgment and lacks the ability to adapt to the complex, heterogeneous health profiles of older patients.

This research, conducted in collaboration between National Cheng Kung University and Canadian institutions, presents a prediction-driven decision model that incorporates patient-specific health states and characteristics to predict future health trajectories. Using a Markov Decision Process (MDP) framework and a 13-year dataset covering over 160,000 older patients in Ontario, Canada, the team developed personalized health transition models and cost functions. The model employs an index policy to prioritize discharge decisions efficiently across patients. Numerical experiments demonstrate the model's ability to reduce hospital costs and length of stay effectively.

This study demonstrates that incorporating machine learning-based predictive information into discharge decisions significantly improves healthcare resource utilization, reduces hospital stay durations and costs, and mitigates the impact of LTC bed shortages.

The model is highly scalable and can be adapted for other regions or patient populations. It may also be integrated with real-time data and electronic health records for dynamic decision-making. Moreover, the approach has the potential to be extended to other healthcare resource allocation challenges, such as surgical scheduling or ICU management.

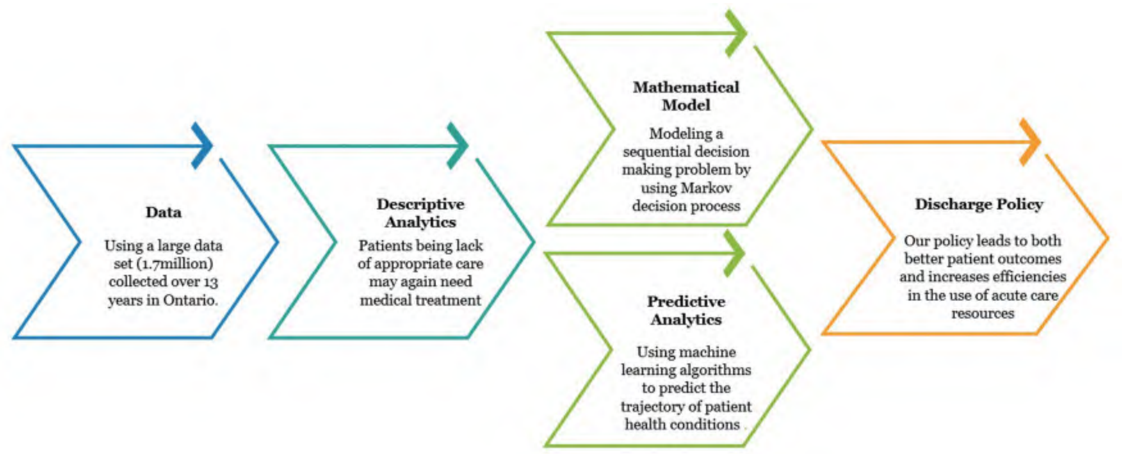

Figure: Modeling Framework

Managing ALC patients efficiently under resource constraints and an aging population is a global healthcare challenge. Decision tools combining AI and operations research offer promising solutions for this pressing issue.

Reference

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