RESEARCH DIGEST

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Features

Special feature of

NCKU 2024 Research Highlights:

Selected Breakthroughs and Applications

Issue 5

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臺灣島的古代酋邦社會

趙金勇，副教授
文學院 / 考古學研究所

趙金勇副教授現任職國立成功大學考古學研究所副教授兼所長；中央研究院歷史語言研究所副研究員。曾在臺灣與美國接受人類學與考古學訓練，期間曾於中國、阿拉斯加與東帝汶等地進行田野工作。2017 年選為台灣考古學會首任理事長。

主要的研究興趣是從歷史生態與演化考古的理路，思考廣義之島嶼東南亞環境變遷與文化適應的複雜關係。近年的研究觸角則延伸到近現代時期的臺灣歷史考古，嘗試豐富對當代社會底層結構的理解。

本研究主要奠基於 2020-2022 與美國西北大學榮譽退休教授 Timothy Earle 的學術合作。

用心閱讀臺灣的朋友總有著一個考古大哉問：臺灣在十七世紀開始出現文獻紀錄以前，到底存在怎樣的社會組織呢？對此，雖然臺灣考古學百年來已經積累極其豐富地下出土的資訊，但是，對於臺灣古代的社會體制卻仍是未解的謎。本研究通過「海洋生產模式」的理論模型，一窺千年之前臺灣古代社會的型態，理解當時複雜的政治經濟決策，成果敦促我們必須從全新的視野去瞭解臺灣島的祖先。

我們分析大量考古資料總結提出，臺灣花東海岸史前時代存在一種獨特的酋邦社會，但有別於傳統概念中認為必須以農業發展出大量集中人口為基石，它是以海洋網絡為經濟核心，更特殊的在於它是人口密度相對低的複雜社會結構。

這裡重要的文化特徵包括：一、區域之間通過財富交換以及廣泛海上貿易形成緊密的政治經濟連結；二、生產模式充分結合陸域農業與海事領域；三、具備造船與航行專業知識的戰士團體，既保護海上貿易也伺機掠劫；四、當地酋長掌握臺灣島內唯一的閃玉礦源，然後通過與跨越南海的長距離海上交換圈，取得島外金屬和玻璃等外來珍稀物，從而掌握政治經濟發展關鍵的瓶頸位置；五、地區性酋長們藉由禮物交換構建並維繫的大範圍的政治聯盟，逐漸深化社會階層化。

就社會複雜化的發展結果而言，此一發展模式由於持續性、長期的海上奇襲掠劫，

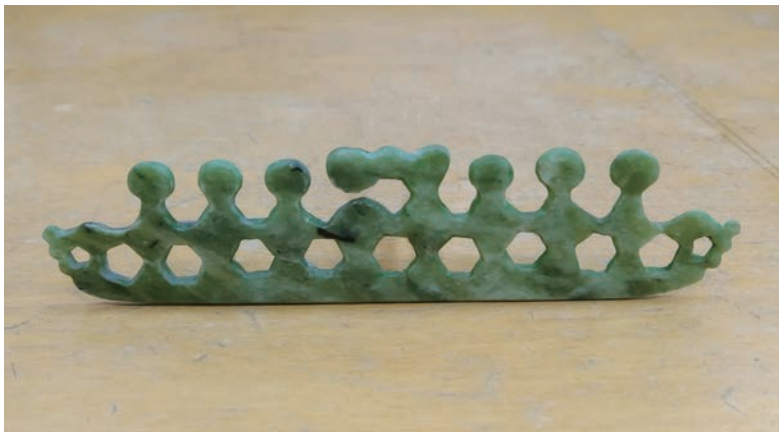
最終導致原本繁榮數千年的花東海岸，在距今約 2000-1200 年前之間反而杳無人煙。滄海桑田，令人不勝唏噓。這些文字無以乘載的臺灣事蹟，再次說明了用土地寫下的歷史。

期刊論文

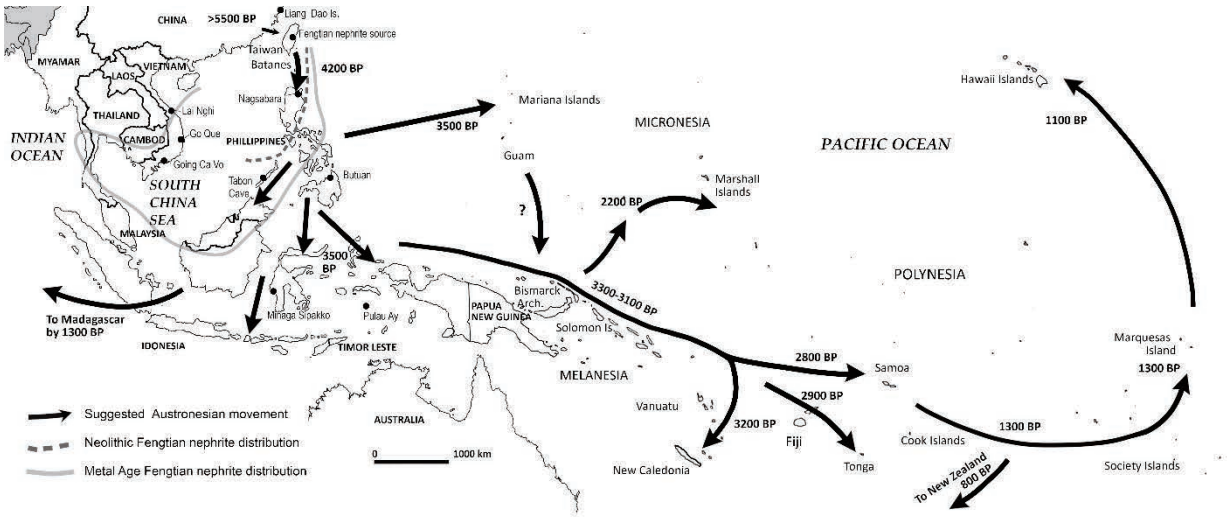
1. “Taiwanese Prehistory: Migration, Trade and the Maritime Economic Mode”. Current Anthropology, 65(4)（2024）: 629-652. (Chin-yung Chao and Timothy Earle 合 著) < https://doi.org/10.1086/730921>

芝加哥大學出版之 Current Anthropology 為英語文獻人類學界首屈一指的第一級期刊。譬如，根據 the Journal Citation Reports: 2021 impact factor 值達 3.226, 在 93 種經調查國際流通的「人類學」類別學術期刊之中，排名第十。2023 JCR Impact Factor: 2.1, Ranked #18 out of 139 “Anthropology” journals; 2023 CiteScore: 5.6 Ranked #15 out of 502 “Anthropology” journals.

2.〈東臺灣史前酋邦社會芻論：一個海洋生產模式的視角〉，郭素秋主編，《臺灣史前文化與原住民人文生態學術研討會論文集》，頁 34-65。臺北：中央研究院歷史語言研究所



臺北芝山岩遺址新石器時代晚期船型玉飾（國立史前文化博物館複製）



臺灣史前南島語族新石器時代（虛線）與金屬器時代（實線）的海上拓殖（依據 Hung and Bellwood, 2024）。灰色虛線標示新石器時代豐田玉的泛南海散佈區域，淡灰色實線則標示金屬器時代範圍（依據 Hung et al. 2012 改繪）

Prehistoric Chiefdoms in Taiwanese Island

Chin-yung Chao, Associate Professor
College of Liberal Arts / Institute of Archaeology

He receives anthropological training in Taiwan and the United States. His primary field study includes China, Alaska and Timor Leste. He was elected as the first President of the Society for Taiwanese Archaeology. His research interests fall mainly in the fields of Social Archaeology and Evolutionary Archaeology, exploring complex strategies when Island Southeast Asia facing rapid environmental changes. He currently touches the subjects on sociocultural processes before and during colonization in Taiwan.

This research is derived largely cooperative study with Timothy Earle Ph.D., Professor Emeritus and former Chair of Anthropology, Northwestern University.

To those who wonder about Taiwan would often ask: what did aboriginal societies in the island look like? Regardless that Taiwanese archaeology over the 120 years developments has provided rich information from the earth, yet the socio-polity status of prehistoric Taiwan remains largely unknown. Through our “Maritime Economic Mode”, this research explores complex political and economic strategies in prehistoric Taiwanese thousands of years ago. It greatly sheds lights on our perspectives to face unspoken past societies.

Through analysis on a large amount of unearthed data, we propose that, unlike common perspective that complex societies base root on developed agriculture, an unique mode of decentralized chiefly societies clearly existed in the eastern coasts, which focused largely on maritime production mode and developed socially complexity through scattered low-density population.

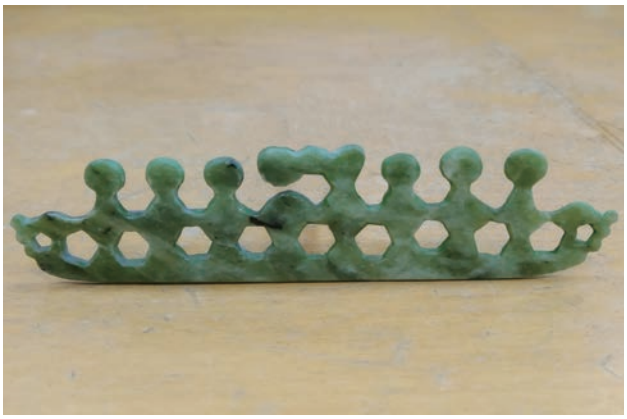
Several characters are argued for eastern Taiwan sequences, including: 1. Emigration and broad interaction, 2. Regional interconnection with local agricultural surpluses finance distant voyaging that an

emergent elite might control, 3. Seaworthy boats building and warriors to protect and raiding, 4. Wealth economy through control over bottlenecks of nephrites and later on iron and glass from abroad, 5. Regional hierarchy through inter-regional alliances.

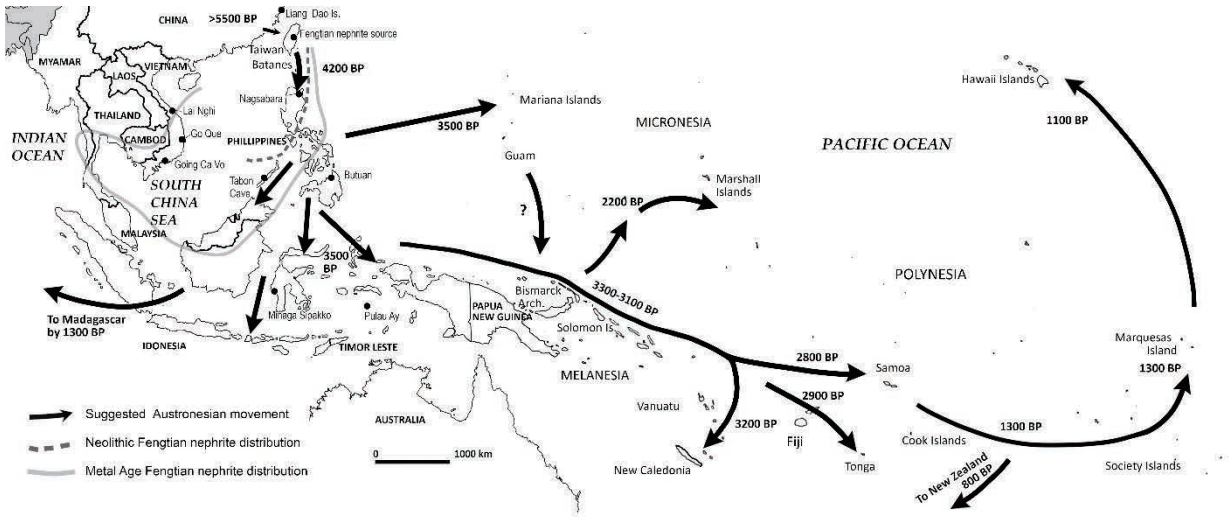
We propose that eastern coast Taiwanese populations developed an entrepreneurial raiding-trading political economy, perhaps involving slaves, that resulted in demographical abandonment of eastern coasts between 2000 and 1200 years ago. Considering eastern coasts have flourished for thousands of years before depletion, it appears that the region witnesses a diverse route of social complexity compared to the western coasts. The scenario can only be unearthed from the ground beneath our feet.

Journal Paper

"Taiwanese Prehistory: Migration, Trade and the Maritime Economic Mode". Current Anthropology, 65(4)（2024）: 629-652. (Chin-yung Chao and Timothy Earle 合著) < https://doi.org/10.1086/730921>



Replica of a Late Neolithic nephrite ornament, likely representing a boat and its crew, photographed in the National Museum of Prehistory, Taitung.



Austronesian expansion out of Taiwan by Neolithic (dash-lined arrows) and Metal Age (solid arrows) times (Hung and Bellwood, 2024). The distributional sphere of Fengtian nephrite during the Middle Neolithic (dashed gray line) and Late Neolithic to Metal Age (light gray line) is shown (redrawn after Hung et al. 2012).

癌症早期檢測新突破：「奈米級螢光元氣彈」問世

—— 葉晨聖，講座教授
理學院 / 化學系

葉晨聖教授現任化學系講座教授，目前專注於奈米材料與生醫領域的跨領域研究，特別是在癌症治療與影像診斷方面取得重大突破，今年也獲頒「2024 侯金堆傑出榮譽獎」。葉教授實驗室的博士後研究員王柳鈞亦在奈米生醫領域耕耘，今年更取得國科會千里馬計畫補助，準備赴英國牛津大學進行研究。此研究成果由化工系田弘康助理教授提供理論計算，也與高醫李偉鵬副教授合作。

癌症長年高居國人十大死因之首，早期檢測對於提升治療成功率至關重要。然而，現有技術在靈敏度與準確度上仍存有諸多限制。為突破這些瓶頸，在國立成功大學化學系葉晨聖講座教授構想下邀請化工系田弘康助理教授以及高雄醫學大學李偉鵬副教授攜手合作，成功研發全球首創「奈米級螢光元氣彈」，為癌症診斷技術開創嶄新契機。

本研究由國立成功大學化學系主導下邀請化工系與高雄醫學大學專家團隊共同推動，融合化學、材料科學與理論計算等領域的專業技術，突破性地提升螢光奈米材料的發光效率，為癌症檢測帶來革新突破。此項研究的關鍵技術為上轉換奈米粒子（UCNPs）與細菌外膜。

上轉換奈米粒子（UCNPs）因能將低能光轉換為高能光，在生物標記、成像與治療領域具有廣泛應用。然而，其亮度受限於稀土離子電子躍遷效率、表面淬滅效應及交叉鬆弛現象，影響成像靈敏度。傳統解決方案如核心殼層設計與金屬增強技術雖能提升發光強度，但仍存技術挑戰。本研究突破現有限制，首度運用細菌外膜增強發光技術，開啟全新方向。

細菌外膜，Shewanella oneidensis MR-1 是一種產電細菌，能將代謝產生的電子透過細胞外電子傳遞（EET）機制輸送至外部氧化

還原物質，以驅動生命活動，如生長、代謝、環境感知與協作。EET 特性使該細菌能將代謝電子傳遞至細胞外環境，對其能量利用至關重要。本研究利用其獨特的電活性，突破性地應用於 UCNPs 的發光增強。

本研究首度發現，Shewanella oneidensis MR-1 的電活性外膜可顯著增強 UCNPs 的發光效率。研究團隊透過脂質體融合膜交換技術，成功從細菌提取電活性脂質體（MILs），並與 UCNPs 結合形成 UCNP@MIL 結構，大幅提升發光強度達 4 倍（如圖 1）。

理論計算（DFT）顯示，電活性外膜可將電子傳遞至 UCNPs 核心，進一步增強發光強度，該機制與細胞色素的分子軌道特性密切相關（如圖 2）。

憑藉優異的螢光特性，UCNP@MIL 材料可應用於細胞層級的癌細胞顯影。實驗結果證明，包覆細菌膜的 UCNPs 能高效標記肝癌細胞，大幅提升成像對比度與精準度（如圖 3）。

葉晨聖講座教授指出，這項技術猶如為癌細胞裝上「發光標記」，即使在極低濃度下，癌細胞仍能清晰呈現，極大提升檢測靈敏度。此技術不僅為奈米醫材領域提供突破性的工具，更有望提升癌症早期診斷的準確度與效率，為未來醫療帶來深遠影響（如圖 4）。

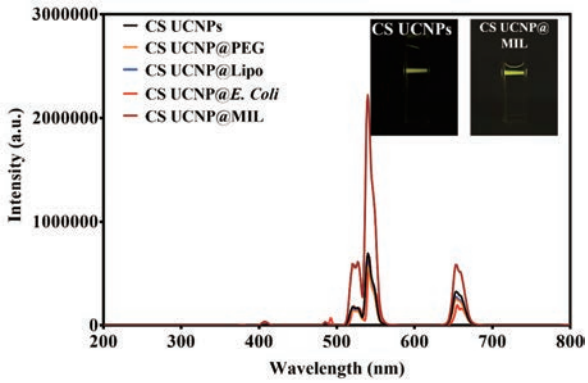


圖 1　無包覆外膜及包覆不同外膜的材料上轉換螢光圖譜。（摘自 Advanced Materials, 2024, 36, 2404120）

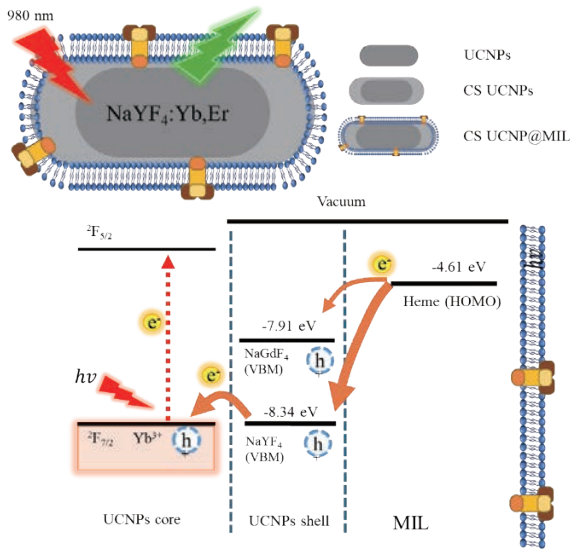


圖 2　奈米級螢光元氣彈機制示意圖。（摘自 Advanced Materials, 2024, 36, 2404120）

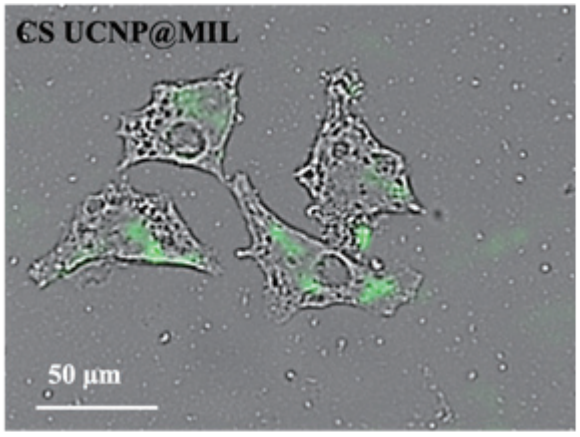


圖 3　放電細菌膜包覆上轉換奈米粒子能產生綠光，用以偵測癌細胞。（摘自 Advanced Materials, 2024, 36, 2404120）

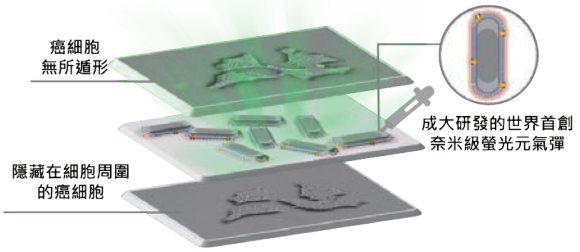


圖 4　癌細胞裝上「發光器」使癌細胞無所遁形的示意圖。

A Breakthrough in Early Cancer Detection: The Launch of the “Nano-Scale Fluorescent Booster”

Chen-Sheng Yeh, Chair Professor
College of Science / Department of Chemistry

Professor Yeh Chen-Sheng is currently a Chair Professor in the Department of Chemistry. He is focused on multidisciplinary research in the fields of Nanomaterials and Biomedicine, with significant breakthroughs in cancer treatment and imaging diagnosis. This year, he was also awarded the “2024 Tung-Ho Outstanding Research Award” Dr. Wang Liu-Chun, a postdoctoral researcher in Professor Yeh’s lab, has been actively working in the field of Nanomedicine and has received the NSTC “Postdoctoral Research Abroad Program” grant this year, preparing to conduct research at the University of Oxford in the UK. The research results were supported by Theoretical Calculations from Assistant Professor Tian Hong-Kang of the Department of Chemical Engineering and in collaboration with Associate Professor Li Wei-Peng of Kaohsiung Medical University.

Cancer remains the leading cause of death in Taiwan, and early detection is critical for effective treatment. However, existing diagnostic methods still face limitations in sensitivity and accuracy. To overcome these challenges, Chair Professor Chen-Sheng Yeh from the Department of Chemistry at National Cheng Kung University leads a multidisciplinary team, in collaboration with Assistant Professor Hong-Kang Tian from the Department of Chemical Engineering and Associate Professor Wei-Peng Lee from Kaohsiung Medical University, to develop the world’s first "Nano-Scale Fluorescent Booster," opening up new opportunities for cancer diagnostics.

This study, led by the Department of Chemistry at National Cheng Kung University, collaborates with experts from the Department of Chemical Engineering and Kaohsiung Medical University. By integrating expertise in chemistry, materials science, and theoretical calculations, the research has achieved a groundbreaking enhancement in the luminescence efficiency of fluorescent nanomaterials, bringing

an innovative breakthrough to cancer detection.Key Technologies: Upconversion Nanoparticles (UCNPs) and Bacterial Outer Membranes

Lanthanide compounds and crystals have long been valued for their fundamental scientific and technological significance. Among them, upconversion nanoparticles (UCNPs) are particularly notable for their ability to absorb two or more low-energy photons and emit high-energy photons, making significant contributions to biological labeling, imaging, and therapeutics.

However, enhancing the brightness of UCNPs remains a challenge due to restricted electronic transitions of lanthanide ions, surface quenching effects, and cross-relaxation phenomena, which limit imaging sensitivity. Traditional approaches, including core-shell design, antenna effects, and metal-induced enhancement, have been explored to address these challenges, but they still face limitations. Our research team overcomes these constraints by pioneering a bacterial outer membrane-assisted fluorescence enhancement technique, providing an innovative direction for biomedical imaging.

The research employs Shewanella oneidensis MR-1, a metal-reducing bacterium with remarkable extracellular electron transfer (EET) capabilities, which enables it to transport electrons from inside the cell to the surrounding environment. This unique ability drives key biological processes, including growth, metabolism, environmental sensing, and microbial interactions.

EET allows Shewanella oneidensis MR-1 to transfer metabolically generated electrons to extracellular redox molecules, which is critical for its survival and energy utilization. Our research harnesses this electroactive property to enhance the luminescence efficiency of UCNPs, achieving a breakthrough in bioimaging applications.

Innovative Technology: Boosting UCNP Fluorescence with Electron-Donating Bacterial Membranes

For the first time, this study demonstrates that the electroactive outer membrane of Shewanella oneidensis MR-1 significantly enhances the luminescence efficiency of UCNPs. Using an innovative liposome fusion-induced membrane exchange (LIME) method, the team successfully extracts electroactive membranes, generating membrane-integrated liposomes (MILs).

By integrating UCNPs with MILs, the research team develops a novel UCNP@MIL structure, achieving a fourfold enhancement in fluorescence intensity (Figure 1).

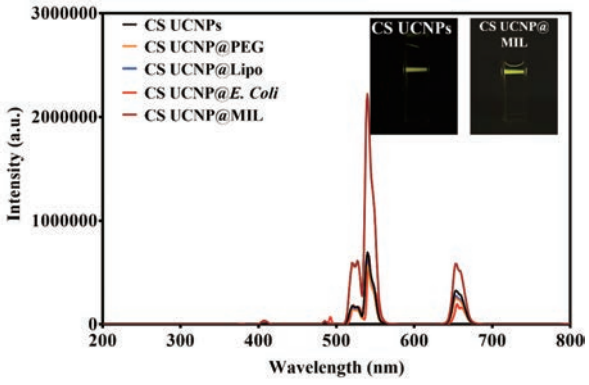


Fig. 1 Upconversion luminescence spectra of materials without membrane coating and with different membrane coatings. (Adapted from Advanced Materials, 2024, 36, 2404120.)

Mechanism of the Nano-Scale Fluorescent Booster

Based on density functional theory (DFT) calculations, the electroactive bacterial outer membrane can transfer electrons through an optically inert shell to the UCNP core, significantly enhancing upconversion luminescence intensity.

This effect arises from the highest occupied molecular orbital (HOMO) energy level of cytochrome being higher than the valence band maximum (VBM) of the shell, enabling efficient electron transfer. A schematic of this mechanism is illustrated in Figure 2.

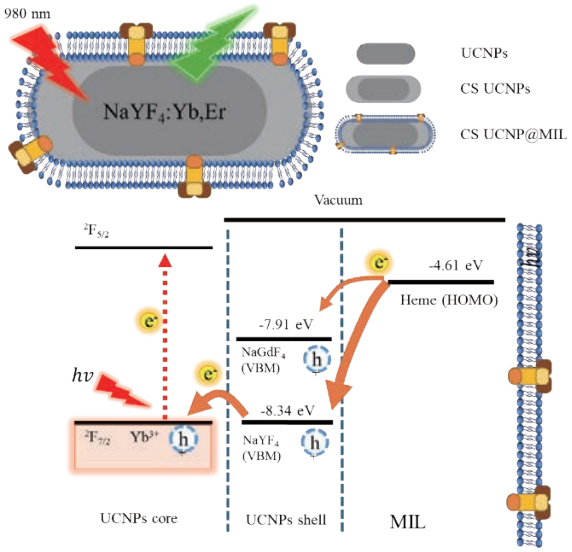


Fig. 2 Schematic illustration of the mechanism of the nano-scale fluorescent booster. (Adapted from Advanced Materials, 2024, 36, 2404120)

Impressive Performance of the Nano-Scale Fluorescent Booster

This material exhibits outstanding luminescence performance, marking a groundbreaking advancement in nanoscale fluorescent probes for cell-level imaging. To evaluate its potential for cellular imaging, the research team conducts examination on liver cancer cells. The results confirm that electron-donating bacterial membranes significantly enhance fluorescence, enabling high-contrast cancer cell imaging (Figure 3).

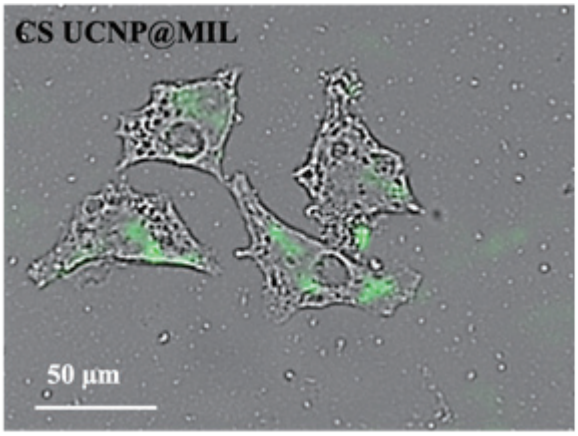


Fig. 3 Electron-active bacterial membrane-coated upconversion nanoparticles emitting green light for cancer cell detection. (Adapted from Advanced Materials, 2024, 36, 2404120.)

Chair Professor Chen-Sheng Yeh highlights that this technology functions as a “light generator” for cancer cells, making them clearly visible even at extremely low concentrations, thereby dramatically improving detection sensitivity.

This innovative advancement provides a powerful tool for nanomedicine, with the potential to significantly enhance the accuracy and efficiency of early cancer diagnostics, contributing to a new era in precision medicine (Figure 4).

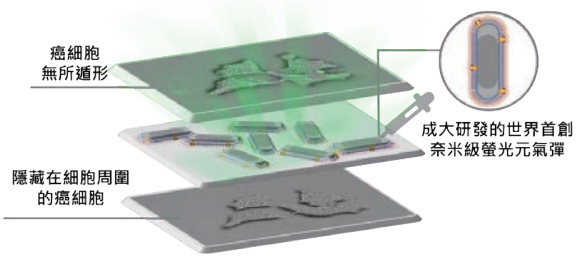
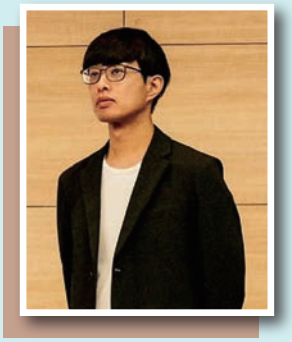


Fig. 4 Illustration of cancer cells equipped with "light generators," making them easily detectable.

成大以科技做外交　協助美國休士頓社區苯汙染研究獲肯定



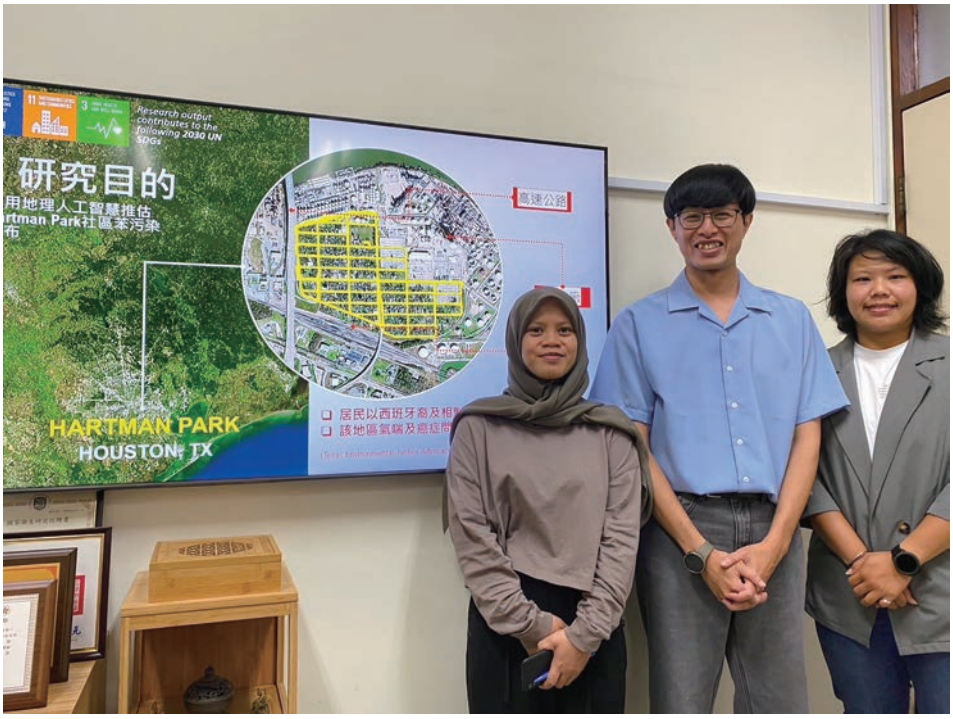
吳治達，教授
工學院 / 測量及空間資訊學系

吳治達博士現為國立成功大學測量及空間資訊學系教授，同時擔任國家衛生研究院國家環境醫學研究所及高雄醫學大學精準環境醫學研究中心兼任研究員。擁有台灣大學森林環境暨資源學研究所博士學位，專長於空氣污染模擬與氣候變遷評估研究。曾多次擔任哈佛大學公衛學院訪問學者。其領導的空間資訊暨環境健康研究室（GEH）專注於運用地理資訊系統與遙感探測技術，結合 Geo-AI 解決環境健康問題。

成功大學測量及空間資訊學系吳治達教授率領研究團隊（成員包含成大食品安全衛生暨風險管理研究所所長陳秀玲、成大測量系博士生 Aji Kusmaning Asri 等），與美國德州農工大學（Texas A&M University）景觀設計及都市計畫學系教授 Galen D. Newman，以及中央研究院環境變遷研究中心副主任龍世俊等重量級學者展開跨國跨域合作，深入分析美國德州休士頓哈特曼公園（Hartman Park）社區的苯污染問題。苯是一種致癌物，已知會增加人類血癌和肺癌等發生機率。哈特曼公園社區居民多為所得相對較低的西班牙裔，長期受到周邊高密度工業區、儲油槽設施等排放的苯污染影響，有社會不公平及環境正義的問題存在。

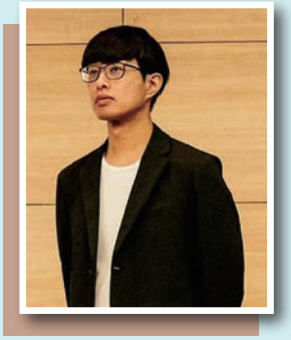
為了精準找出苯污染的來源與分布，吳治達教授的團隊創新運用地理人工智慧（GeoAI）技術。這項技術巧妙地結合了地理資訊系統（GIS）的空間分析能力，以及人工智慧（AI）的大數據處理優勢，如同為環境監測裝上智慧大腦，能高效分析複雜的環境數據。藉由 GeoAI 技術的加持，研究團隊得以高達 98% 的準確度，精確模擬苯在社區內的分布狀況，更從超過 300 項環境因子中，精確鎖定四大關鍵汙染因素，包括：氣溫、工業區、老舊破損的儲油槽，以及交通相關因子（如高速公路等）。

本次雙邊合作源於環境部化學物質管理署的計畫，邀請美國德州農工大學超級基金研究中心（Texas A&M University Superfund Research Center）來臺訪問，促成了此次合作。研究成果獲得美方高度肯定，並已發表於國際期刊《危險物質》（Journal of Hazardous Materials）。此研究可廣泛應用於各類環境污染監測與防治，為全球永續發展貢獻臺灣力量。



成大測量系教授吳治達（中）團隊協助美國德州休士頓社區進行當地苯汙染的地理人工智慧分析，獲得美方肯定，左為團隊成員博士生 Aji、右為博士生王琬茹。

NCKU applied science and technology as diplomacy, and its assistance in investigating benzene concentration in the Hartman Park community, Houston, Texas, USA was recognized



Chih-Da Wu, Professor
College of Engineering /
Department of Geomatics

Dr. Chih-Da Wu is currently a Professor in the Department of Geomatics at National Cheng Kung University, and also serves as an Adjunct Research Fellow at the National Institute of Environmental Health Sciences, National Health Research Institutes, and the Precision Environmental Medicine Research Center, Kaohsiung Medical University. He holds a Ph.D. in Forestry from National Taiwan University, with expertise in air pollution modeling and climate change impact assessment. Dr. Wu has been a visiting scientist at Harvard T.H. Chan School of Public Health multiple times. His Geomatics and Environmental Health Laboratory (GEH) focuses on applying Geographic Information Systems and remote sensing technologies, integrated with Geo-AI, to address environmental health issues.

TProfessor Chih-Da Wu from the Department of Geomatics at National Cheng Kung University (NCKU), leading a research team (including Professor Hsiu-Ling Chen, Director of the Department of Food Safety / Hygiene and Risk Management at NCKU, and Dr. Aji Kusmaning Asri, a PhD candidate in Geomatics at NCKU), collaborated with Professor Galen D. Newman from the Department of Landscape Architecture and Urban Planning at Texas A&M University, and Dr. Shih-Chun Lung, Deputy Director of the Research Center for Environmental Changes at Academia Sinica. This cross-national and interdisciplinary collaboration focused on analyzing the benzene pollution problem in the Hartman Park community of Houston, Texas, USA. Benzene, a known carcinogen, is linked to an increased risk of blood and lung cancers. The Hartman

Park community, primarily composed of low-income Hispanic residents, has long been affected by benzene pollution from surrounding high-density industrial areas and storage tank facilities, raising concerns about social inequity and environmental justice.

To precisely identify the sources and distribution of benzene pollution, Professor Wu's team innovatively applied Geospatial-Artificial Intelligence (GeoAI) technology. This technology cleverly integrates the spatial analysis capabilities of Geographic Information Systems (GIS) with the big data processing advantages of artificial intelligence (AI). Like equipping environmental monitoring with an intelligent brain, it can efficiently analyze complex environmental data. With the assistance of GeoAI technology, the research team was able to accurately simulate the benzene distribution within the community at 98% accuracy, and from over 300 environmental factors, precisely identify four key pollution drivers: air temperature, industrial areas, aging and damaged storage tanks, and transportation-related factors (e.g., highways).

This bilateral collaboration originated from a program initiated by the Ministry of Environment's Chemical Substances Management Agency, which invited the Texas A&M University Superfund Research Center to visit Taiwan, facilitating the present collaboration. The study has received significant recognition from the U.S. research community and has been published in the prestigious international journal "Journal of Hazardous Materials." This research can be widely applied in various environmental pollution monitoring and prevention efforts, contributing Taiwan's expertise to global sustainable development.

Journal Paper

What is the spatiotemporal pattern of benzene concentration spread over susceptible area surrounding the Hartman Park community, Houston, Texas? / Journal of Hazardous Materials / 0304-3894 /20240521

The team led by Dr. Chih-Da Wu (middle) from the Department of Geomatics at National Cheng Kung University assisted the Hartman Park community in Houston, Texas, USA, with a geographical artificial intelligence analysis for estimating benzene levels. On the left is team member, doctoral student Aji, and on the right is doctoral student Wan-ru Wang."

* 圖與圖說來自成大新聞中心：

https://web.ncku.edu.tw/p/406-1000-268860,r3636.php?Lang=zh-tw

https://web.ncku.edu.tw/p/406-1000-268892,r3635.php?Lang=en

鏈接水資源：區塊鏈技術驅動的智慧水庫控制安全

劉奕賢，助理教授
電機資訊學院 / 電機工程學系

劉奕賢博士是國立成功大學電機工程學系暨智慧資訊安全碩士學位學程助理教授，研究專長涵蓋工控網路安全、電腦網路及資安試驗平台等。劉博士是成大資通安全研究與教學中心的核心成員之一，負責其關鍵基礎設施資安試驗平台建置相關工作，相關成果曾獲國科會前瞻資安科技專案計畫優良計畫團隊與 111 年度成果發表最佳人氣獎等肯定。

水庫作為水資源管理的核心設施之一，對於調節洪水、防止乾旱、保障供水穩定至關重要。然而，隨著極端氣候的頻發和網絡威脅的日益嚴峻，傳統水庫營運面臨前所未有的挑戰。如何在保障水資源安全的同時，提升水庫系統的可靠性和智慧化程度，成為當前亟待解決的關鍵問題。目前水資源領域中，仍十分依賴相關人員進行操作及記錄等程序，在人手不足的窘境下，如何確保操作及記錄的正確，同時也希望能以低碳的方式為環境永續盡一份心力，故我們團隊包含李忠憲教授、莊坤達教授等專家學者，在國科會及水利署的支持下，以實際水庫控制系統為基礎，建置水壩控制系統資安試驗平台，並運用區塊鏈技術來協助避免相關記錄被篡改的風險，為水庫的操作及狀態監控提供了全新的解決方案。透過我們發展的相關異常操作檢測機制，可以快速有效的發現操作中的異常行為，避免可能引發的運行失誤，讓災害消彌於無形之中，我們的機制得以更簡潔的方式運行，而不需要龐大的計算資源，且幾乎沒有誤報的情況發生，可大幅減少人員因處理誤報警告的負擔。我們同時也開發了 MiniDAM 的實驗軟體，以數位孿生技術，提供水壩控統系統相關的模擬環境，包含相關設備的操作指令及其相關網路流量的資料集等，為科學研究提供寶貴的資料參考。未來，我們的研究還可以延伸至運用智慧生活、

智慧工廠等場域之中，用來避免相關錯誤操作所導致的危害。水庫營運的智慧化和安全化不僅關乎水資源的永續利用，更對於社會穩定和經濟發展具有深遠影響，透過我們的研究成果，將推動水資源管理進入全新階段，為全球水安全問題提供切實可行的解決方案。

期刊論文

1. Common Criteria for security evaluation and malicious intrusion detection mechanism of dam SCADA system/IET Networks/ 2047-4954 /06 June 2024

2. Cross-organizational Non-repudiation Industrial Control Log System Based on Blockchain/ Journal of Robotics, Networking and Artificial Life/ 2405-9021 /20 December 2022

獎項

2024 年第六屆綠點子國際發明暨設計競賽 銀牌

2023 國科會前瞻資安科技專案計畫 111 年度成果發表最佳人氣獎

2023 第十三屆網路智能與應用研討會 (NCWIA 2023) 最佳論文獎

圖 1 a & b 大壩控制系統網路安全測試平台
由國家科學技術委員會和水利署支持下建置的大壩控制系統網路安全測試平台位於本校安南校區。該平台幫助我們測試並提高水資源管理系統的安全性，確保它們安全且有效率地運作。

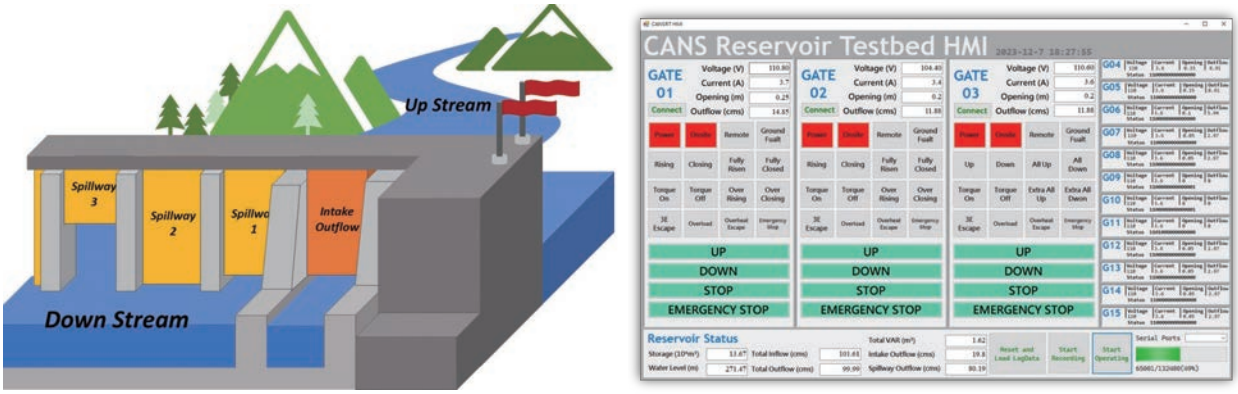


圖 2 a & b MiniDAM 模擬場景及軟體畫面
我們團隊開發了一個名為「MiniDAM」的虛擬水庫模擬系統，設計了一個水庫營運的圖控介面，提供相關監控管理的功能，同時提供相關的操作模擬。

Chaining Water Resources: Blockchain-Driven Intelligence Reservoir Control and Safety

I-Hsien Liu, Assistant Professor
College of Electrical Engineering and Computer Science / Department of Electrical Engineering

Dr. I-Hsien Liu is an assistant professor in the Department of Electrical Engineering and the Master Program in Cyber-Security Intelligence at National Cheng Kung University. His research focuses on industrial control systems, network security, computer networks, and cybersecurity testbeds. As a core member of the Taiwan Information Security Center at National Cheng Kung University, he plays a key role in developing critical infrastructure security testbed. Leveraging this testbed, his team has developed various protection technologies, acquired multiple invention patents, and assisted government agencies in strengthening the security of their control systems. His contributions have been widely recognized, including awards of excellence team, and the Best Popularity Award at the 2022 Annual Results Presentation from the National Science and Technology Council's Advanced Information Security Technology Project. Moving forward, Dr. Liu continues to advance cybersecurity research, aiming to enhance the resilience and security of critical infrastructure systems.

Reservoirs play a vital role in managing water resources. They help control floods, prevent droughts, and ensure a stable water supply for both human consumption and agricultural needs. However, with the increasing frequency of extreme weather events and the growing threats from cyberattacks, traditional reservoir operations are facing new and unprecedented challenges. The key question today is how we can protect and efficiently manage water resources while making reservoirs more reliable, intelligent, and resilient in the face of these evolving threats. Climate change and natural disasters are intensifying, placing more pressure on reservoir systems to function reliably under extreme conditions. Meanwhile, the rise of cyber threats poses significant risks to the integrity of the control systems that operate these critical infrastructures. The question is: how do we balance the need for security, efficiency, and sustainability? Currently, the water resource sector still heavily relies on manual operations and record-keeping processes. Given the shortage of personnel, ensuring

the accuracy of operations and records is a pressing concern. Additionally, there is a growing need to adopt low-carbon solutions to contribute to environmental sustainability. In response to these challenges, our team, including Professor Jung-Shian Li and Professor Kun-Ta Chuang, with the support of the National Science and Technology Council and the Water Resources Agency, has developed a cutting-edge cybersecurity platform specifically for reservoir control systems. We have integrated blockchain technology—a powerful tool known for providing secure, decentralized, and tamper-proof records—into the core of our reservoir management system. Our research has also developed an anomaly detection mechanism for operational errors. This mechanism allows for the rapid and effective identification of irregularities in system operations, preventing potential operational failures before they escalate into disasters. Unlike conventional systems, our mechanism operates efficiently without requiring extensive computational resources, significantly reducing false alarm occurrences. This, in turn, alleviates the workload of personnel who would otherwise need to handle false alerts, improving operational efficiency and reliability. By detecting these issues early, we can prevent costly and potentially dangerous mistakes, ensuring that the reservoirs continue to operate safely and efficiently. This innovation not only solves important technical challenges but also offers a model for applying cutting-edge technologies to other industrial control systems. To further enhance our research, we've created MiniDAM, an experimental software that utilizes digital twin technology to simulate reservoir control systems in a virtual environment. This tool replicates the real-world operations of reservoirs, including the control systems, operational commands, and network traffic patterns. Researchers can use this simulated environment to test various scenarios, analyze data, and fine-tune the system to improve its performance. By using digital twins, we can predict how a reservoir will react under different conditions, helping to improve decision-making and operational planning. These advancements aren't limited to water management alone. Our developed technologies can be applied to other smart control scenarios, such as power grids, transportation networks, and manufacturing processes. The same principles that enhance water resource management can be extended to ensure the security and efficiency of other critical infrastructure systems. Smart and secure reservoir operations are essential for preserving water resources and ensuring societal stability and economic development. Effective water management supports agriculture, industry, and urban development, contributing to the overall well-being of communities. As these technologies continue to evolve, they will help revolutionize how we manage and protect our vital water resources, offering practical solutions to address the global water security challenges faced by many countries around the world. The integration of blockchain, artificial intelligence, and digital twin technology will play a pivotal role in shaping the future of water management, ensuring that reservoirs operate with greater security, efficiency, and sustainability.This

research alleviates unnecessary concerns among pregnant women worldwide regarding the potential impact of GDM on their children's health. It also enhances the accuracy of medical decision-making and treatment interventions, helping to prevent unnecessary healthcare expenditures. Furthermore, the study highlights Taiwan's capabilities in medical big data research and international collaboration, providing more precise scientific evidence for maternal and child healthcare worldwide while further elevating Taiwan's influence in global medical research.

Journal Paper

1. Common Criteria for security evaluation and malicious intrusion detection mechanism of dam SCADA system/IET Networks/ 2047-4954 /06 June 2024

2. Cross-organizational Non-repudiation Industrial Control Log System Based on Blockchain/ Journal of Robotics, Networking and Artificial Life/ 2405-9021 /20 December 2022

Fig. 1 a & b Dam Control Systems Cybersecurity Testbed

The dam control systems cybersecurity testbed, supported by the National Science and Technology Council and the Water Resources Agency, is located at the Annan Campus of NCKU. This platform helps us test and improve the security of systems that manage water resources, ensuring they operate safely and efficiently.

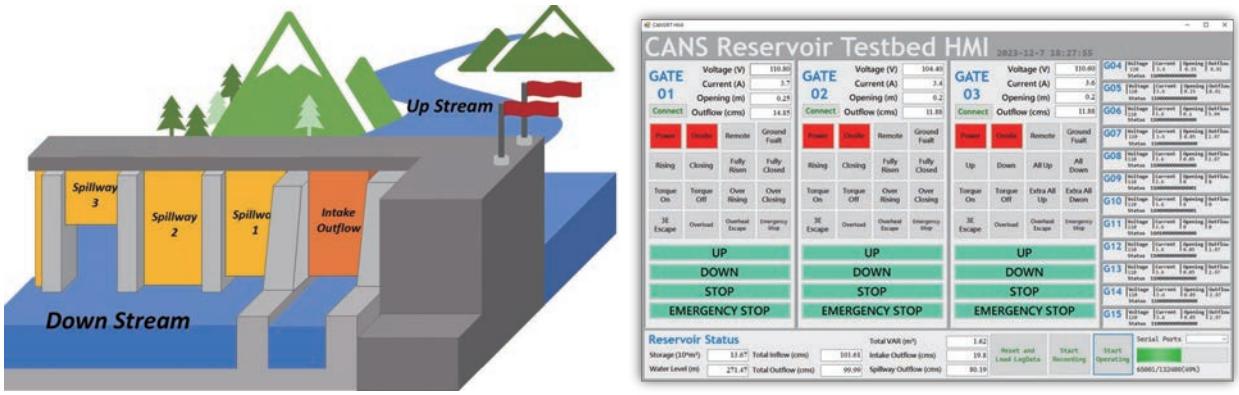


Fig. 2 a & b MiniDAM simulation scenarios with Software GUI

Our team has developed a virtual reservoir simulation system called "MiniDAM," which includes a control interface for reservoir operations. This system offers various monitoring and management functions, as well as the ability to simulate operational scenarios. With this system, I can simulate and control different parameters of reservoir operations, helping me better understand and practice water management processes. It serves as an effective tool to optimize the operation of real-world reservoirs.

衰弱肌少症的專家—智遊科技首創居家 sEMG 量測與訓練整合系統

林彥呈，教授
規劃與設計學院 / 工業設計學系

林彥呈教授為工業設計博士，目前服務於成大工業設計學系教授暨生物醫學工程學系合聘教授，研究著重於整合智慧醫療與互動科技等領域。林教授並擔任成大衍生新創公司「智遊科技」的創辦人，智遊科技結合在地文化，把復健變互動遊戲，並創首款居家 sEMG 量測技術。此外，林教授團隊於 2021 年參加 Stanford Center on Longevity Design Challenge，於全球 37 個國家中脫穎而出，榮獲全球前八強，也是台灣唯一團隊。

隨著高齡化的社會來臨，高齡者因年齡增長產生衰弱肌少的症狀，增加高齡者跌倒的風險，進而產生其他併發症；加上醫院人滿為患，無法安排最適化的療程，更錯失黃金治療期的最佳療效，亦增加家人生活的負擔。再者，傳統的徒手肌力訓練與輔具訓練等復健模式，除了無法辨識高齡者的復健進展，亦無法吸引高齡者自主性使用。此系統主要解決的痛點，在於目前高齡族群居家復健多以徒手為主，缺乏系統化、智慧化與數位化記錄工具。

本研究為跨領域研究團隊的合作，並與成功醫院共同合作，並以培養科技輔具系統跨領域研發人才，加速高齡族群輔具的研究發展，提升我國高齡族群健康照護水準；並與歐盟（捷克科技大學）進行跨國產學國際合作，計畫名稱「國際合作鏈結法人 - 高齡者遠距醫療之智慧健促服務系統」（如圖 1 所示）。

本系統具有三大特色：「智慧化」以人工智慧輔助專業人員評估療程、「遊戲化」透過懷舊遊戲增加復健動機、以及「客製化」根據個案客製化專屬療程。本系統透過互動體感與懷舊遊戲，喚起高齡者共鳴並增加復健動機（如圖 2 所示）。本系統可偵測各肌群

圖 1 本跨領域研究團隊與歐盟（捷克科技大學）進行國際合作

圖 2 本遊戲設計依據歷史照片並結合臺灣 1960 年代的柑仔店文化，增加高齡者持續使用遊戲復健之動機，同時藉由虛擬教練之輔助角色，使得高齡者進行正確復健動作訓練

在訓練時的情況，藉由 AI 技術進行步態分析及評估高齡長者衰弱狀況，協助醫療專業人員給予高齡者最準確的復健方案，並同時將訓練狀況傳送給家人，讓家人可以清楚知道高齡者的復健進展。

創全球首款居家 sEMG 量測技術 - 結合在地文化，把復健變互動科技。這套系統在《寶島探險》的遊戲包裝下，除了是一套可具療效的復健系統外，其專利的智慧護膝，更創下目前全球首款在居家智慧輔具上，運用表面「肌電訊號」(sEMG) 量測的數位記錄。

提供新型居家復健服務系統，減少高齡者與家人的生活負擔，提供最適化的復健療程。同時，可服務偏鄉地區積極推動肌少症檢測標準流程，篩檢出肌少症之偏鄉高齡者，縮短城鄉醫療差距，進而達到在地老化、健康老化、活耀老化目標 (如圖 3 所示)。

圖 3 本系統可紀錄高齡者復健時肌肉活動的生理數據，也可提供專業醫療人員一項有利的評估工具，進而給予客製化的復健訓練內容

獎項

2024 德國 IF（International Forum Design）產品設計獎。

2024 NHQA 國家醫療品質獎 傑出醫療類金獎。

2023 榮獲第 20 屆國家新創獎（連續三年獲獎）。

2022 SNQ 國家醫療品質獎 智慧醫療方案解決組品質標章。

2021 榮獲 2021 第 18 屆育秀盃設計大賽 工業設計類金獎，獎金十五萬元整。

2021 Stanford Center on Longevity Design Challenge 全球前 8 強（台灣唯一）。

2020 榮獲龍騰微笑智聯網創業競賽最大獎（貳獎，首獎從缺），獎金一百萬元整。

2020 榮獲 Panasonic 2020 綠色生活創意設計競賽通用設計類 金獎，獎金二十萬元整。

Sarcopenia Expert – aiFree Pioneers the First Home-use sEMG Measurement and Training Integration System

Yang-Cheng Lin, Professor
College of Planning and Design / Department of Industrial Design

Prof. Lin holds a PhD in industrial design and is currently a professor in the Department of Industrial Design and a joint professor in the Department of Biomedical Engineering at National Cheng Kung University. His research focuses on the integration of smart medicine and interactive technology. Prof. Lin also founded "aiFree Interactive Technology Co.," a new start-up company from NCKU. The aiFree combines local culture to turn rehabilitation into interactive games, and develops the first home-use sEMG measurement system. In addition, Prof. Lin's team participated in the Stanford Center on Longevity Design Challenge in 2021 and stood out among 37 countries worldwide, winning the Top 8 and being the only team in Taiwan.

With the advent of an aging society, older adults are at risk of experiencing symptoms of weakness and Sarcopenia, increasing the risk of falls and other complications. In addition, hospitals are overcrowded and cannot arrange optimal treatment courses, resulting in the golden treatment period being missed, and increasing the burden on family members. Furthermore, traditional rehabilitation ways (such as manual muscle strength training and assistive device training) cannot identify the rehabilitation progress of older adults, and attract them to continuous rehabilitation. The main pain-points are that the current home rehabilitation relies on bare hands and lacks systematic, intelligent, and digital recording tools.

This cross-field research team, which cooperated with Cheng Kung Hospital, aims to cultivate cross-field research talents for smart medical assistive devices for older adults, thus improving the health care. We also conduct cross-industry-

academic international cooperation with the European Union (Czech Technical University in Prague), and the project name is "International Bilateral Project- the Smart Health Promotion Service System for Older Adults" (as shown in Figure 1).

This system has three major features: "Intelligentization" uses artificial intelligence to assist professionals in evaluating treatment courses; "Gamification" uses nostalgic games to increase motivation for rehabilitation, and "Customization" customizes exclusive treatment courses according to individual cases. This system uses interactive somatosensory and nostalgic games to arouse the resonance of older adults and increase their motivation for rehabilitation (as shown in Figure 2). This system can detect the condition of each muscle group during training, use AI technology to analyze gait and assess the frailty of older adults, assist medical

Fig. 1 This cross-field research team cooperated with the European Union (Czech Technical University in Prague)

Fig. 2 The interactive somatosensory games can arouse the resonance of older adults and increase their motivation for rehabilitation

professionals in giving their most accurate rehabilitation plan, and at the same time transmit the training status to family members, so that family members can clearly understand the rehabilitation progress of older adults.

We pioneered the world's first home-use sEMG measurement technology and combined it with Taiwan's local culture. In addition to serving as a treatment and rehabilitation system, its patented smart knee brace also develops a digital medical record.

We provide a new home rehabilitation service system to reduce the living burden of older adults and their family members, and provide optimal rehabilitation treatments. At the same time, it can serve rural areas and actively promote the standard process for sarcopenia testing, screen out older adults in rural areas with sarcopenia, shorten the medical gap between urban and rural areas, and achieve the goals of local aging, healthy aging, and active aging (as shown in Figure 3).

Journal Paper

1.Chang CH, Wei CC, Yang TH, Lien WC, Liu B, Lin YM, Tan PT, Lin YC. The usability and effect of a novel intelligent rehabilitation exergame system on quality of life in frail older adults: Prospective cohort study. JMIR Serious Games. 2025 Jan; 13: e50669

2.Chang CH, Lien WC, Chiu TP, Yang TH, Wei CC, Kuo YL, Yeh CH, Liu B, Chen PJ, Lin YC. A novel smart somatosensory wearable assistive device for older adults' home rehabilitation during the COVID-19 pandemic. Front Public Health. 2023 Sep; 11: 1026662.

3.Chang CH, Yeh CH, Chang CC, Lin YC. Interactive Somatosensory Games in Rehabilitation Training for Older Adults With Mild Cognitive Impairment: Usability Study. JMIR Serious Games. 2022 Jul; 10(3): e38465.

4.Lien WC, Yeh CH, Chang CY, Chang CH, Wang WM, Chen CH, Lin YC. Convolutional Neural Networks to Classify Alzheimer's Disease Severity Based on SPECT Images: A Comparative Study. Journal of Clinical Medicine. 2023 Mar; 12(6): 2218.

Fig. 3 This system provides medical professionals with powerful assessment tools to customize rehabilitation training content

邁向可靠衛星影像生成模型：超快速高光譜影像壓縮感知與融合

許志仲，副教授
管理學院 / 數據科學研究所

許志仲博士致力於電腦視覺與深度學習在影像處理、深偽辨識、超解析及醫學影像分割等領域之創新應用，其成果發表於 IEEE TPAMI、TIP、TMM、TGRS、ACM MM、ICIP 等頂尖期刊與會議，研究成果屢獲國際競賽殊榮。其團隊於國際挑戰賽中展現實力，許博士亦獲得有庠科技論文獎、未來科技獎等榮譽。

您是否曾想過，我們每天使用的天氣預報、環境監測、甚至農作物生長狀況分析，都與遙遠的衛星息息相關？衛星影像技術的發展，對我們的生活影響深遠。然而，傳統衛星影像處理面臨著諸多挑戰，例如：資料量過大導致傳輸困難、影像解析度不足、真偽難辨等。我們成功克服了這些挑戰，為我們帶來更清晰、更安全、應用更廣泛的未來！

由數據所許志仲副教授領導，以及 ACVLab 同學，開發出「超快壓縮感知技術」。這項技術如同魔術般，在衛星上就能將龐大影像資料「瘦身」，僅需簡單數學運算，不需複雜硬體。即使資料大幅壓縮，仍可利用少量訓練資料，重建出高品質影像。

更進一步，團隊研發出融合不同光譜影像的技術，如同疊合照片，呈現更豐富細節。同時，加入防止影像造假的技術，讓衛星影像更值得信賴。這些成果已獲國際肯定，發表於遙測領域頂尖期刊《IEEE Transactions on Geoscience and Remote Sensing》（TGRS）及國際會議 IGARSS。

此項技術突破，將如何影響我們的生活？

- 更精準的環境監測：更清晰的影像，能更準確監測氣候變遷、預測災害，及時提供防災資訊。
- 更有效率的資源管理：農民可精確掌握作物生長，優化灌溉施肥，提高產量。
- 更安全的國土防衛：提升遙測影像真實性，有助於國土安全監控。
- AI 結合的廣大應用：未來將與 NVIDIA Research Taiwan 合作，結合大型語言模型（LLM），將大幅提升資料處理效率，為高光譜影像技術開啟智慧城市、精準醫療等多元應用。

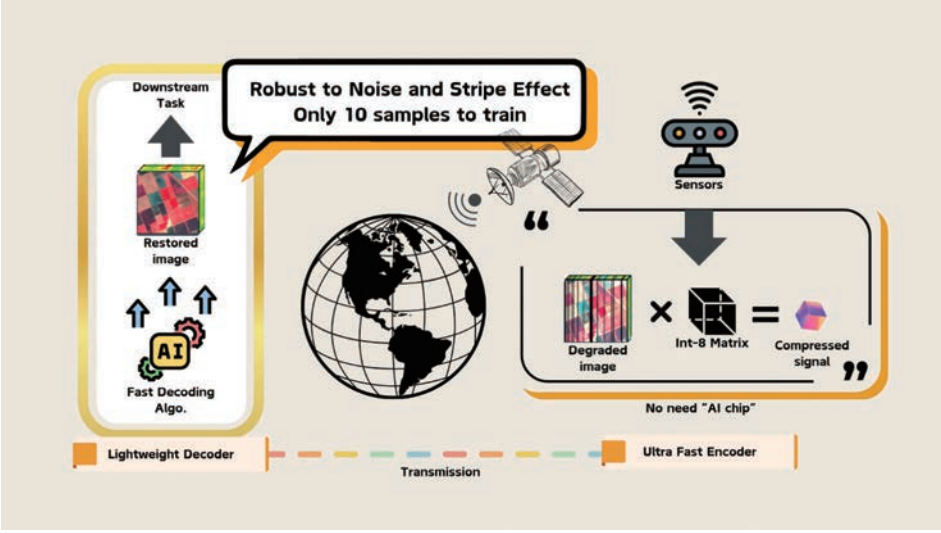
團隊的突破，不僅展現臺灣在太空科技的實力，更為社會的永續發展，開啟無限可能。

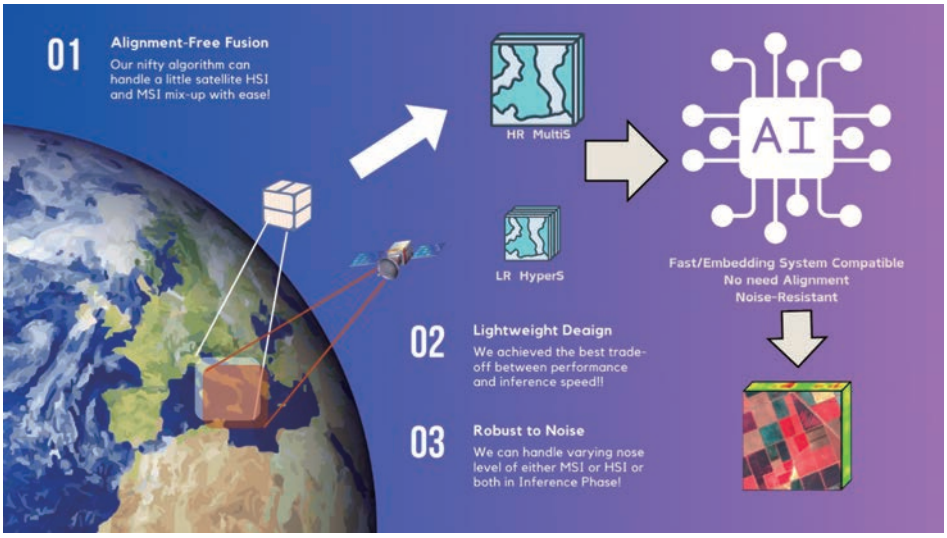
期刊論文

1.1.C.C. Hsu*, C.Y. Jian, E.S. Tu, C.M. Lee, and G.L. Chen, “Real-Time Compressed Sensing for Joint Hyperspectral Image Transmission and Restoration for CubeSat,” in IEEE Transactions on Geoscience and Remote Sensing, to appear. (IF: 8.2, Rank 29/1409=2% in Electrical and Electronic Engineering)

2.C.C. Hsu, C.M. Lee, and Y.S. Chou, “DRCT: Saving Image Super-Resolution away from Information Bottleneck,” IEEE/CVF Computer Vision and Pattern Recognition Conference (CVPR2024), New Trends in Image Restoration and Enhancement (NTIRE) Workshop, accepted.

3.C.C. Hsu and M.Z. Ke, “Seeing is NOT Believing: Toward Forgery Detection for Hyperspectral Image,” IEEE International Geoscience and Remote Sensing Symposium (IGARSS), July 2023.

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Alignment-Free Fusion
Our nifty algorithm can handle a little satellite HSI and MSI mix-up with ease!
HR MultiS
LR HyperS
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Fast/Embedding System Compatible
No need Alignment
Noise-Resistant
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Lightweight Deaign
We achieved the best trade-off between performance and inference speed!!
03
Robust to Noise
We can handle varying nose level of either MSI or HSI or both in Inference Phase!


ACVLab/Chih-Chung Hsu
2023 IEEE IGARSS
About Our Vision & Mission
1
First Fake Hyperspectral Dataset
5 types of forged hyperspectral images
Partial and complete spectral information missing
2
Hyperspectral Forgery Detection
Developing the novel detector based on HR-Net
First detection method of forged hyperspectral images
3
Secured Protocol (in Progress)
Make the connection even more robust
HyperForensics
https://cchsu.info

Towards Reliable Satellite Image Generative Models: Ultra-Fast Hyperspectral Images Compressed Sensing and Fusion

Chih-Chung Hsu, Associate Professor
College of Management / Institute of Data Scienc

Dr. Chih-Chung Hsu is dedicated to the innovative application of computer vision and deep learning in image processing, DeepFake detection, super-resolution, and medical image segmentation. His work has been published in top-tier journals and conferences such as IEEE TPAMI, IEEE TIP, IEEE TMM, IEEE TGRS, ACM MM, and IEEE ICIP, and his research achievements have been repeatedly recognized in international competitions. His team has demonstrated outstanding performance in global challenges, and Dr. Hsu himself has received prestigious honors including the YouXiang Technology Paper Award and the Future Technology Award.

Have you ever considered that the weather forecasts, environmental monitoring, and even crop growth analyses we rely on daily are all connected to distant satellites? The development of satellite imaging technology has a profound impact on our lives. However, traditional satellite image processing faces numerous challenges, such as: excessive data volume leading to transmission difficulties, insufficient image resolution, and difficulties in verifying authenticity. We have successfully overcome these challenges, paving the way for a future with clearer, more secure, and more widely applicable satellite imagery!

Body:

Led by Associate Professor Hsu Chih-Chung of Institute of Data Science and the students of ACVLab, the team has developed "Ultra-fast Compressive Sensing Technology." This technology acts like magic, enabling

the "slimming down" of massive image data directly on the satellite, requiring only simple mathematical operations and no complex hardware. Even with significant data compression, high-quality images can still be reconstructed using a small amount of training data.

Furthermore, the team has developed technology to fuse images from different spectral bands, similar to merging photographs, to present richer details. Simultaneously, anti-image forgery technology has been incorporated, making satellite imagery more trustworthy. These achievements have received international recognition, with publications in the top-tier remote sensing journal, IEEE Transactions on Geoscience and Remote Sensing (TGRS), and the international conference IGARSS.

How will this technological breakthrough impact our lives?

- **More Precise Environmental Monitoring**: Clearer images enable more accurate monitoring of climate change and prediction of natural disasters, providing timely information for disaster prevention and mitigation.
- **More Efficient Resource Management**: Farmers can precisely monitor crop growth, optimize irrigation and fertilization, and increase yields.
- **Enhanced National Security**: Improving the authenticity of remote sensing imagery contributes to national security monitoring.
- **Vast AI-integrated Applications**: The project plans to cooperate with NVIDIA Research Taiwan, combining Large Language Models (LLMs) to significantly improve data processing efficiency. This will contribute to applications of hyperspectral imaging technology in diverse fields, such as in smart cities and precision medicine.

Conclusion:

The team's breakthrough not only demonstrates Taiwan's strength in space technology but also opens up endless possibilities for the sustainable development of society.

Journal Paper

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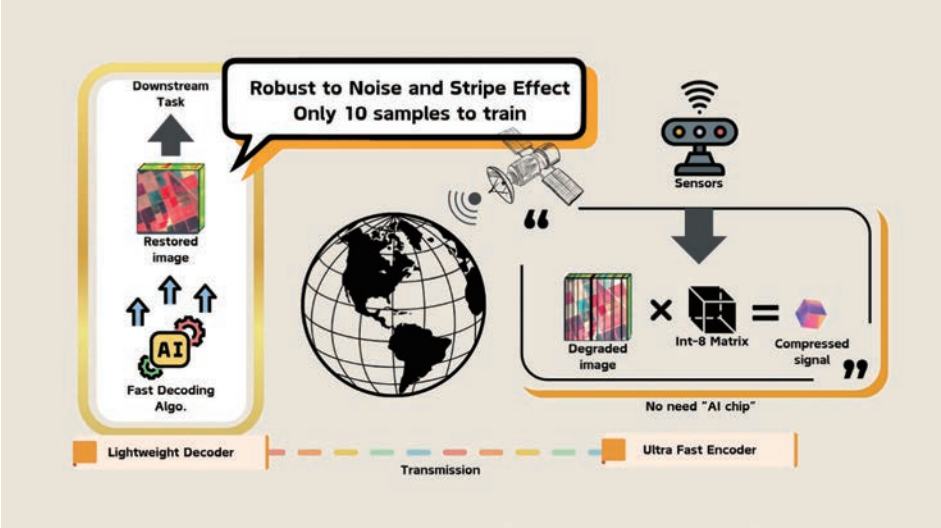
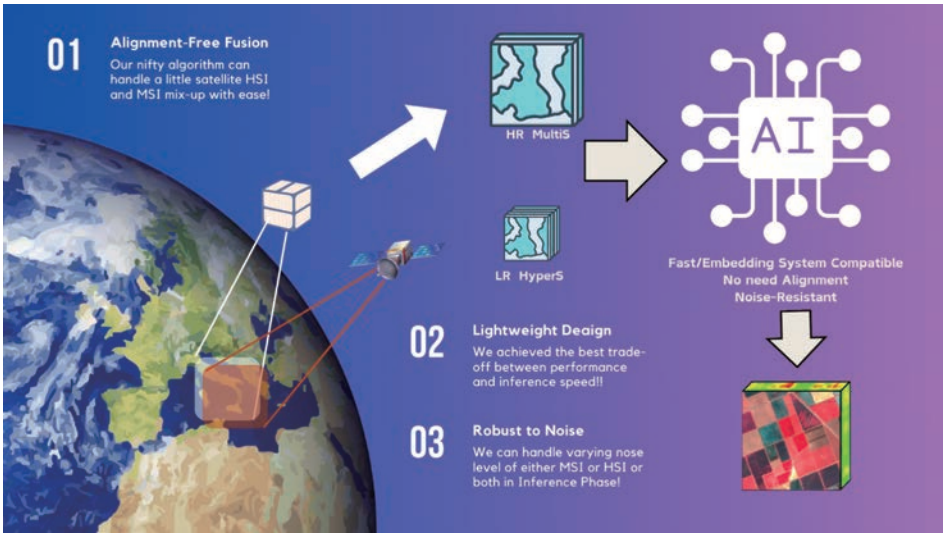

Downstream Task
Restored image
AI
Fast Decoding Algo.
Robust to Noise and Stripe Effect
Only 10 samples to train
Sensors
Degraded image
Int-8 Matrix
Compressed signal
No need "AI chip"
Lightweight Decoder
Transmission
Ultra Fast Encoder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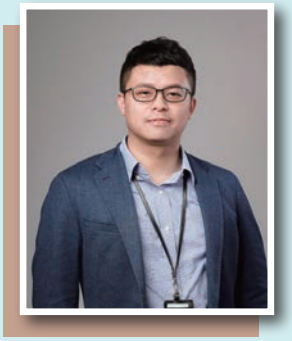
全球最大規模母子配對巨量資料分析：孕期糖尿病並非造成子代注意力不足過動症的原因

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，實現從「Taiwan can help」到「Taiwan can lead」的願景。

過去關於孕期糖尿病是否會增加子代罹患注意力不足過動的風險，以及是否應使用降血糖藥物進行控制等議題，相關研究相當有限。成功大學賴嘉鎮教授團隊攜手國際組織 NeuroGEN，結合來自臺灣、紐西蘭、香港、芬蘭、冰島、挪威及瑞典等七個國家的健康數據，涵蓋超過 6,000 萬人口，納入 360 萬對母子配對資料，進行全球規模最大的巨量資料分析。本研究運用頂尖的大數據

賴嘉鎮教授於國科會記者會說明本研究計畫（照片攝於 2024.06）

統計分析技術，並採用手足對照設計等進階流行病學研究方法，透過比較個案的兄弟姊妹，以有效排除環境與基因遺傳等可能的干擾因素，精準推論孕期糖尿病與子代過動症之間真正的因果關係。研究成果推翻過去研究的認知，證實孕期糖尿病並非造成子代過動症的原因，也提供降血糖藥物使用策略與合理性等相關證據。此研究不僅減輕了全球孕婦對孕期糖尿病可能影響子代健康的無謂擔憂，也使醫療決策與治療介入更加精確，避免不必要的醫療資源浪費。此外，研究成果突顯臺灣在醫療大數據研究與國際合作的實力，並為全球孕婦與兒童健康醫療提供更精確的科學實證，進一步提升臺灣在國際醫學研究領域的影響力。

期刊論文

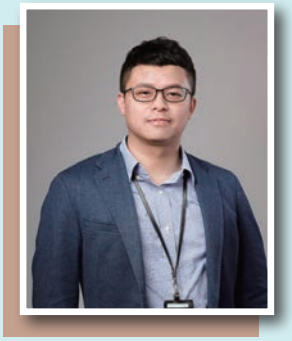
Maternal diabetes and risk of attention-deficit/hyperactivity disorder in offspring in a multinational cohort of 3.6 million mother–child pairs/ Nature Medicine/ 1416–1423/ 08 April 2024

賴嘉鎮教授與其領導的成大群體健康數據中心研究團隊（照片攝於 2024.05）

賴嘉鎮教授說明臨床試驗與真實世界數據之差異（照片攝於 2024.06）

35

Largest Global Mother-Child Pairs Big Data Study: Gestational Diabetes Is Not a Key Risk Factor for ADHD in Offspring



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

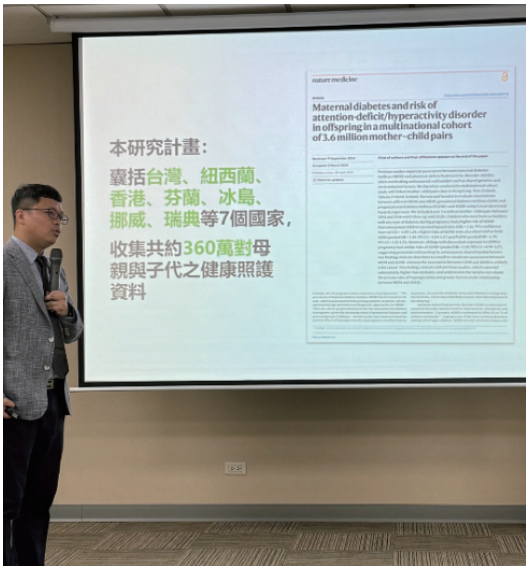
Professor Edward Chia-Cheng Lai leverages real-world data from Taiwan, integrating clinical contexts with pharmacoepidemiologic research designs to transition from observing phenomena to establishing causal relationships in research. Under his leadership, the Population Health Data Center has been actively 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."

Research on whether gestational diabetes mellitus (GDM) increases the risk of attention-deficit/hyperactivity disorder (ADHD) in offspring and whether blood glucose-lowering medications should be used for management has been relatively limited. To address this gap, Professor Edward Chia-Cheng Lai's team at National Cheng Kung University collaborated with the international organization NeuroGEN, integrating health data from seven countries—Taiwan, New Zealand, Hong Kong, Finland, Iceland, Norway, and Sweden. This extensive dataset encompasses over 60 million individuals and includes 3.6 million mother-child pairs, making it the largest large-scale data analysis on this topic worldwide.

Utilizing state-of-the-art big data statistical analysis techniques and advanced epidemiological research methods, the study employed a sibling comparison design to minimize the influence of genetic and environmental confounders. By comparing siblings within the same family, the

researchers were able to precisely infer the true causal relationship between GDM and ADHD in offspring. The findings challenge previous research conclusions, confirming that GDM is not a direct cause of ADHD in offspring. Additionally, the study provides evidence regarding the appropriateness and rationale for using glucose-lowering medications during pregnancy.

This research alleviates unnecessary concerns among pregnant women worldwide regarding the potential impact of GDM on their children's health. It also enhances the accuracy of medical decision-making and treatment interventions, helping to prevent unnecessary healthcare expenditures. Furthermore, the study highlights Taiwan's capabilities in medical big data research and international collaboration, providing more precise scientific evidence for maternal and child healthcare worldwide while further elevating Taiwan's influence in global medical research.



Professor Edward Chia-Cheng Lai explained this research project at the NSTC press conference (photo taken in June 2024).

Reference

Maternal diabetes and risk of attention-deficit/hyperactivity disorder in offspring in a multinational cohort of 3.6 million mother–child pairs/ Nature Medicine/ 1416–1423/ 08 April 2024

Professor Edward Chia-Cheng Lai, Director of the Population Health Data Center, and his team members (photo taken in May 2024).

Professor Edward Chia-Cheng Lai explained the differences between clinical trials and real-world data (photo taken in June 2024).

“多為他人想，少為自己想”的雙方互惠研究

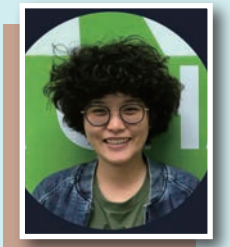
龔俊嘉，教授
社會科學院 / 心理學系


龔俊嘉教授


陳德祐副教授


翁明宏副教授


劉世南特聘教授


王樂斯


張宜晴

我們是一群對神經經濟學，社會神經科學，與進階實驗及分析方法有興趣的研究者。成員包括（但不限於）：成大經濟系、心理系，臺大國企系，及 MRI 中心的博後及學生等。一開始純為了交流彼此對共同議題的興趣，逐漸演變成搭配國科會計畫的申請與執行，及深耕共同目標的跨研究室討論。研究議題往往跟社會神經科學有關，例如神經經濟學，多機 fMRI 實驗（hyperscanning）及資料分析等。

社會神經科學旨在瞭解社會現象中，複雜現象後各自與共同的神經機制。而在本實驗研究中，團隊藉由修改經濟學賽局理論中的「協調 / 合作賽局」，探討多人的兩兩互動中，合作 / 競爭與個人特質（互利 vs. 獨佔 v.s. 退讓型）的交互作用。盼能管窺在團隊默契形成與維持等動態歷程中的大腦機制。此篇研究為本團隊在多機掃瞄系列研究的第二篇，也是世界的第二篇，臺灣的第一篇，三機 fMRI 的研究，標幟著本校跨領域團隊的長期合作成果。

fMRI（功能性磁振造影）自 1992 年的第一篇研究以來，絕大多數的發表都是單機單人掃瞄。2002 年才有第一篇兩人連線的同步超掃瞄（hyperscanning）實驗（Montague et al., 2002），但仍受限於技術的挑戰，發表不多。藉由成員的長期合作，本團隊於 2022 年發表了雙機跨大腦共頻（coherence）的分析文章（Wang et al., 2022）。進而於去（2024）年三月發表了三校（臺、政、成大）三機連線（見圖一）的超掃瞄研究，豐富臺灣社會神經科學的研究能量。本團隊掌握了臺灣唯一，世界亦有限的「多機連線造影技術」。意即在絕大多數的功能性磁振造影實驗多為單人單機進行的情況下，多人多台 MRI 機器的同時連線造影，賦予社會科學家更多窺探複雜社會互動現象——即時多人大腦運作機制的機會。

本篇文章題目「較為他人著想，較少為自己的兩人，能夠在你來我往的遊戲中得到較多」的發現 (Wang et al., 2024)，主要是由文章的圖三（附圖）而來：當依其作答的樣態把受試者分為三種群體：分別為合作 (reciprocal)、寡佔 (dominant)、順從 (submissive) 時，發現到兩人若能有來有往的的互惠，雙方皆能得到最大利益（相較於一味的全拿型、或是一味的順服型、參與者）。而其大腦中主司「推論他人」的顳頂葉交界處 (Temporal-Parietal Junction, TPJ) 與負責「自我利益」的內頂葉 (Inferior Parietal Lobule, IPL) 的功能性腦區相關，恰巧與受試者所得利益成負相關一亦即平均賺得最多的受試者，他們大腦中 IPL 反應較低（少想到自己），TPJ 反應較高（多想到他人），進而功能性相關為負。

此研究非但提供了吾人社會交往中的大腦神經證據，也進一步的說明：多數臺灣學生展現出成熟公民的樣態一樂於合作，多為他人著想，並非一味退讓或一味強拿。它揭示了從簡單的人際到複雜國際博弈，皆一體適用的「平等互惠」原則。在人類共同面對的重大問題，如全球暖化、貧富不均等，提供重要的參考。

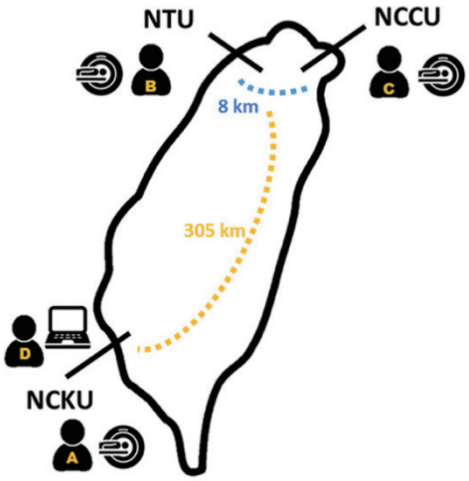


圖 1(a)　三機 fMRI 實驗圖：位在臺大、政大（相距 8 公里）、成大（與兩校相距 305km) 三校 fMRI 連線的實驗，是臺灣的第一篇，世界的第二篇，三機 fMRI 研究論文，亦標示著本校跨領域團隊的長年合作成果之一。

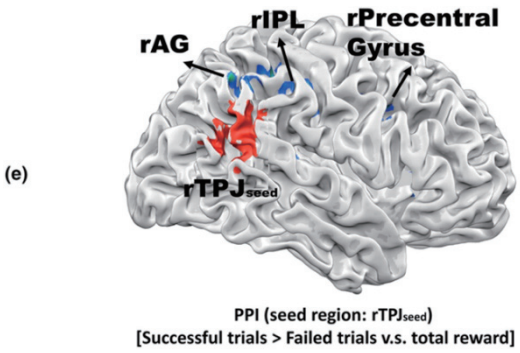


圖 2　本三機 fMRI 研究的腦區位置圖，rTPJ (right Temporal-Parietal Junction 右腦的顳頂葉交界處），rIPL (right Inferior Parietal Lobule, 右腦的下頂葉），紅色表示為正向活化反應，藍色為負向活化反應。

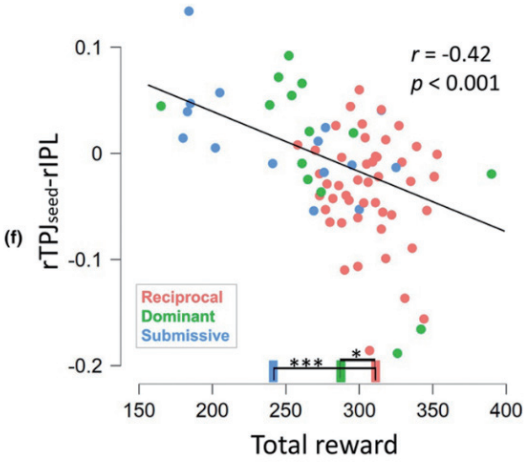


圖 3　散佈圖顯示每位參與者最後所獲得總酬賞與右顳頂葉交界處 (rTPJ) 與右側下頂葉 (rIPL) 間有顯著負相關。三種類型的參與者反應可區分為互惠型（紅色）、主導型（綠色）和順從型（藍色）。x 軸上的條形代表三種類型的平均總獎勵：互惠（NT $ 307.82），主導（NT $ 274）和服從（NT $ 247.28）。散點圖表明，獲得最多獎勵的互惠組個體（Nred=49，紅色）（r=-.054，p=.713）的 rTPJ - rIPL 連接性最低，其次是主導組個體（Ngreen=14，r=-.610，p=.021)；最差是順從組 (Nblue=15, r=-.570, p<.27) 的參與者。

When "more for others, less for self" leads to co-benefits: A tri-MRI dyad-hyperscanning study

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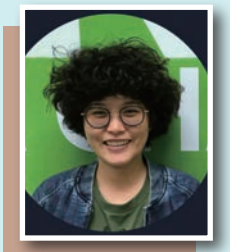
Le-Si Wang


Yi-Cing Chang

We are a group of researchers interested in neuroeconomics, social neuroscience, and advanced experimental and analytical methods. Members include (but not limited to): faculties, postdocs, and students from the Department of Economics, Psychology (both from NCKU), the department of International Business in NTU, and the NCKU MRI Center. In the beginning, it was purely for the exchange of mutual interests on common topics, and gradually evolved into a discussion forum on the NSTC-funded research projects. Research topics are often related to social neuroscience, such as neuroeconomics, multi-MRI (hyperscanning) and data analysis, etc.

Social neuroscience aims to understand the individual and common neural mechanisms of complex social phenomena. In this experiment, the team explored the interaction between cooperation/competition and personal traits (reciprocal vs. dominant vs. submissive) in the interaction of multiple people by modifying the "coordination/cooperation game" from the economics game theory. We hope to get a glimpse of the brain mechanism in the dynamic process of team tacit formation and maintenance. This study is the second in a series of hyperscanning publications by our team, the second in the world, and the first in Taiwan.

Since the first publication of fMRI, or functional magnetic resonance imaging, in 1992, the vast majority of publications have been single MRI scans. It was until 2002 that the first two-person fMRI hyperscanning experiment (Montague et al., 2002) was published, but it was still limited by technical challenges and there were not many related publications. Through the long-term collaboration among the members, our team published an analysis of dual-scanner inter-

brain coherence in 2022 (Wang et al., 2022). In March 2024, the hyperscanning study of the three-MRI connection (see Figure 1) of the three universities (NCKU, NCCU, and NTU) was published, enriching the research energy of social neuroscience in Taiwan. Our team has mastered the only "multi-scanner parallel imaging technology" in Taiwan (and among a few in the world). This means that while the vast majority of MRI experiments are carried out by a single machine, multiple scanners are connected simultaneously, giving social scientists more opportunities to peek into the complex phenomenon of social interaction—the real-time mechanism of intra- and inter-brain processing.

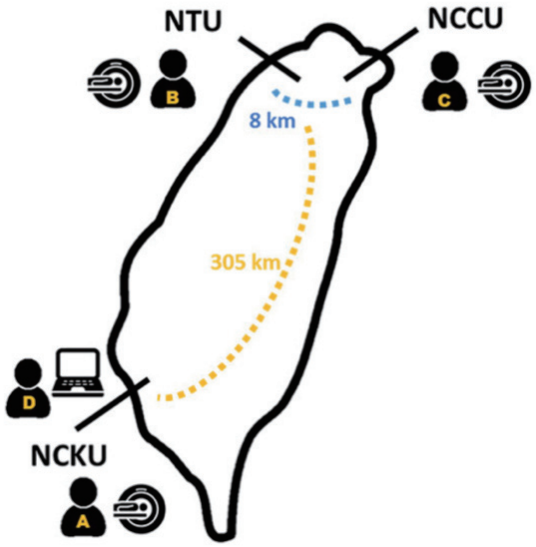

Fig. 1 The fixed roles of the triads respectively in the three fMRI sites across Taiwan, National Cheng-Kung University (NCKU), National Taiwan University (NTU), and National Cheng-Chi University (NCCU). NTU and NCCU are in northern Taiwan, 8 km away, while NCKU is in southern Taiwan, 305 km apart from NTU and NCCU. This 3-MRI hyperscanning paper, likely the 2nd in the world, and the 1st in Taiwan, marks the fruit of our cross-disciplinary collaborations throughout the years.

Our title, "when ‘more for others, less for self’ leads to co-benefits" (Wang et al., 2024) was mainly derived from Figure 3 of the article: When the subjects were divided into three groups according to their answers: reciprocal, dominant, and submissive, the reciprocal participants get the most rewards (as opposed to the take-all, or the submissive participants). The Temporal-Parietal Junction (TPJ), which is responsible for "inferring others", is negatively correlated with the Inferior Parietal Lobule (IPL), which is responsible for "self-interest", and their negative correlations also correlates with their rewards received—that is, the subjects who earn the most on average have lower IPL responses (less thinking about themselves) and higher TPJ responses (thinking more about others) in their brain.

This study not only provides neurological evidence of our brain's social interactions but also reflects that most Taiwanese (students) show the signs of matured citizens - willing to cooperate, more considerate of, and not

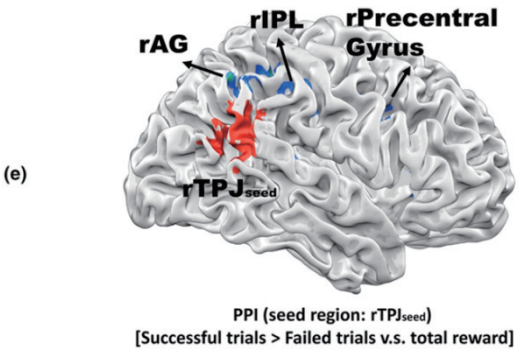

Fig. 2 Brain area location map of this three-machine fMRI study. rTPJ (right temporoparietal junction) and rIPL (right inferior parietal lobule). Red color represents positive neural responses, whereas blue color denotes negative ones.

blindly yield to, nor blindly force, others. It reveals the principle of equality and reciprocity, which universally applies from simple interpersonal to complex international games. Such conclusion also has profound implications for major problems faced by mankind, such as global warming and inequality between the rich and the poor.

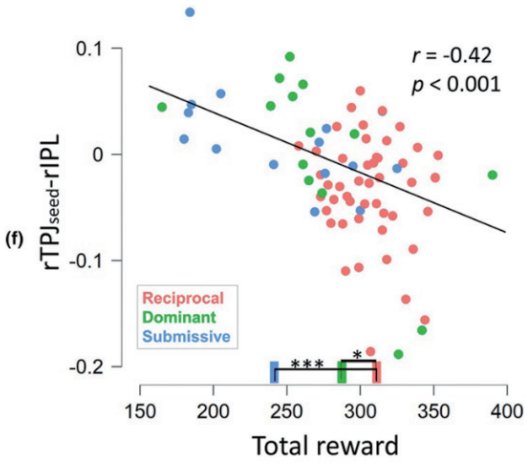

Fig. 3 The scatter plot shows the significant negative correlations between the total reward and the rTPJ–rIPL connectivities. The three types of participants were reciprocal (red), dominant (green) and submissive (blue). The bars on the x-axis represent the mean total reward of the three types: reciprocal (NT$ 307.82), dominant (NT$ 274) and submissive (NT$ 247.28). The scatter plot suggests the reciprocal individuals (Nred = 49, in red), who earned the most reward (r = -.054, p = .713) got the lowest rTPJ–rIPL connectivity, followed by the dominant (Ngreen = 14, r = -.610, p = .021); and then the submissive (Nblue = 15, r = -.570, p < .27) participants.

Journal Paper

When "more for others, less for self" leads to co-benefits: A tri-MRI dyad-hyperscanning study/ Psychophysiology/10.1111/psyp.14560 /2024.Mar

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全球山區氣候速度與生物追蹤反應

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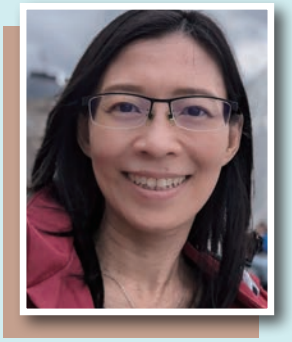

作者群

本研究團隊包含兩位通訊作者，成功大學生命科學系陳一菁教授以及中研院生物多樣性研究中心沈聖峰研究員，第一作者為哈佛大學 Museum of Comparative Zoology 博士後研究員詹偉平；法國 Jonathan Lenoir 研究員 (Universit de Picardie Jules Verne, France) 匯集 BioShift 資料庫，蒐集過去百年、超過三萬筆生物分布改變資訊；臺灣大學大氣系郭鴻基教授提供大氣動力專業，以及中研院麥館碩參與分析。

摘要

本研究結合衛星數據與熱力學原理，首度評估全球山區氣候變遷速度。研究發現 17 個山區正經歷快速氣候變化，包括阿拉斯加 - 育空地區及日本、蘇門答臘等生物多樣性熱點，揭示山區氣候變遷異速機制，為保育策略提供科學基礎。

關鍵字：溫度遞減率、等溫線遷移、高風險山區、生物分布改變

前言

山區是全球生物多樣性的重要庇護所，然而氣候變遷正對這些脆弱的生態系統構成威脅。隨著氣候暖化，生物大規模往高海拔遷移以維持適合的溫度環境，但是否能夠追上溫度移動（即氣候速度），至今難以準確評估，主要是因為山區氣象站極為有限。在全球氣候變化加速的背景下，評估山區氣候速度、判斷生物反應是否夠快，變得尤為迫切，這也是本研究希望解決的核心問題。

突破性方法與技術創新

結合衛星遙測數據與熱力學基本定律，突破山區氣象資料不足的困境，首次全面量化全球山區的氣候速度，提供了完整的全球山區氣候變遷圖像。

關鍵發現

1. 全球高風險區域：全球 32% 的山區正經歷相對高速的氣候變遷，分布於 17 個高風險山區，從阿拉斯加 - 育空到南非、從地中海到東南亞，橫跨各種氣候條件，與多個生物多樣性熱點重疊。

2. 水汽影響：研究發現除溫度上升外，空氣中的水汽含量也顯著影響氣候速度。濕潤氣候降低溫度遞減率，反而導致更快的氣候變遷速度，解釋了蘇門達臘、巴西高地等濕潤地區呈現高氣候速度的原因。

3. 區域差異：北半球的中低海拔與高緯度山區氣候速度最快，島嶼山區（包括臺灣、日本）的氣候速度顯著高於大陸山脈，表明島嶼生物多樣性面臨更大威脅。相較之下，喜馬拉雅山、安第斯山等高海拔地區的變化速度較慢。

4. 生物反應：研究團隊分析生物分布變化資料庫，評估生物反應是否跟上氣候速度。結果顯示，在氣候速度較低的區域，生物仍有機會追上氣候變化，凸顯減緩全球暖化、以及維持棲地連續性，對幫助生物移動、適應氣候變遷的重要性。

結論與未來展望

這項發表於《Nature》的研究首次全面量化全球山區氣候變遷速度，呈現不同山區面臨不均等的氣候威脅。研究指出全球 32% 的山區正經歷高氣候速度，揭示水汽條件的重要影響及島嶼山區（包括臺灣）的特殊挑戰。

研究結果也帶來希望，在氣候速度較低的山區，生物仍有適應機會，表明積極減緩氣候變遷與維持棲地完整性，仍可有效保護山區生物多樣性。

加強全球山區氣象監測網絡，特別是濕度與水汽條件的評估，方能精確追蹤山區複雜的氣候變化。這項研究不僅具學術價值，也為全球山區保育政策提供科學基礎，對臺灣等島嶼國家更具重要參考意義。

結語

這項《Nature》研究展現臺灣研究團隊的國際影響力，也提醒我們山區生態系統的脆弱性與保育迫切性。在氣候變遷加劇的時代，唯有基於科學證據的積極行動，才能確保山區這一全球生物多樣性寶庫的永續未來。

期刊論文

Chan, W.-P., Lenoir, J., Mai, G.-S., Kuo, H.-C., Chen, I.-C., & Shen, S.-F. (2024). Climate velocities and species tracking in global mountain regions. Nature, 629, 114–120. https://doi.org/10.1038/s41586-024-07264-9

圖 1 日本為生物多樣性熱點，但面臨更高的氣候速度 _ 陳一菁攝於日本常念岳

圖 2 島嶼氣候速度高於大陸山區，威脅生物多樣性 _ 陳一菁攝於蘭嶼

圖 3 阿拉斯加山區也屬於氣候變遷高風險區 _Jonathan Lenoir 攝於南阿拉斯加 Chugach National Forest

Climate velocities and species tracking in global mountain regions

I-Ching Chen, Professor ‧ Vice Dean
College of Bioscience and Biotechnology /
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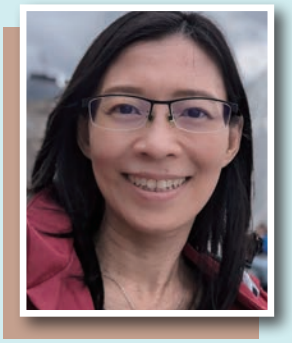

The research team includes two corresponding authors: Professor I-Ching Chen from the Department of Life Sciences at National Cheng Kung University and Dr. Sheng-Feng Shen, Research Fellow at the Biodiversity Research Center, Academia Sinica. The first author is Dr. Wei-Ping Chan, a postdoctoral researcher at Museum of Comparative Zoology, Harvard University. Dr. Jonathan Lenoir (Université de Picardie Jules Verne, France) compiled the BioShift database, collecting information on over 30,000 species distribution changes over the past century. Professor Hung-Chi Kuo from the Department of Atmospheric Sciences at National Taiwan University provided expertise in atmospheric dynamics, while Guan-Shuo Mai from the Biodiversity Research Center at Academia Sinica participated in the analysis.

Abstract

This study combines satellite data with thermodynamic principles to conduct the first comprehensive assessment of climate change velocity in global mountain regions. The research identifies 17 mountain areas experiencing rapid climate change, including Alaska-Yukon and biodiversity hotspots like Japan and Sumatra. The findings reveal mechanisms behind varying climate change velocities in mountains, providing scientific guidance for conservation strategies.

Keywords: Lapse Rate of Temperature, Isotherm Shift, High-velocity Mountain Regions, Species Range Shifts

Mountains serve as crucial refuges for global biodiversity, yet face mounting threats from climate change. As temperatures rise, species migrate to higher elevations, but whether they can keep pace with temperature shifts—known as climate velocity—has been difficult to assess due to limited mountain weather stations. This pioneering research addresses the urgent challenge.

The team combined satellite remote sensing data with thermodynamic principles to overcome insufficient meteorological data in mountain regions. This breakthrough enabled the first comprehensive quantification of climate velocities across global mountain systems.

Key Findings:

1. Global High-Risk Regions: 32% of global mountain areas are experiencing relatively rapid climate change, spanning 17 regions from Alaska-Yukon to South Africa, from the Mediterranean to Southeast Asia—overlapping with numerous biodiversity hotspots.

2. Water Vapor Effects: The research reveals that atmospheric water vapor significantly influences climate velocity. A previously overlooked aspect is that humid climates reduce temperature lapse rates,

accelerating climate change velocity—explaining why humid regions like Sumatra and the Brazilian Highlands exhibit high climate velocities.

3. Regional Variations: Changes are most pronounced in mid-to-low elevation and high-latitude mountain regions in the Northern Hemisphere. Island mountain systems (including Taiwan and Japan) show significantly higher climate velocities than continental ranges, indicating greater threats to island biodiversity.

4. Species Response: Analysis of over 30,000 species distribution records shows that in areas with lower climate velocities, species still have opportunities to adapt, highlighting the importance of mitigating global warming and maintaining habitat connectivity.

Published in *Nature*, this research confirms different mountain regions face unequal climate threats. The findings offer hope: in regions with lower climate velocities, species can adapt, suggesting that mitigating climate change and maintaining habitat integrity can effectively protect mountain biodiversity.

The research team recommends strengthening global mountain meteorological monitoring networks, especially for humidity conditions. This study provides a scientific foundation for mountain conservation policies, with particular relevance for island nations like Taiwan.

Professor Chen's team has provided crucial scientific evidence for understanding the challenges facing mountain biodiversity. This *Nature* publication demonstrates Taiwan's research impact while highlighting the urgency of conservation efforts in mountain ecosystems—Earth's treasured reservoirs of biodiversity.

Journal Paper

Chan, W.-P., Lenoir, J., Mai, G.-S., Kuo, H.-C., Chen, I.-C., & Shen, S.-F. (2024). Climate velocities and species tracking in global mountain regions. Nature, 629, 114–120. https://doi.org/10.1038/s41586-024-07264-9

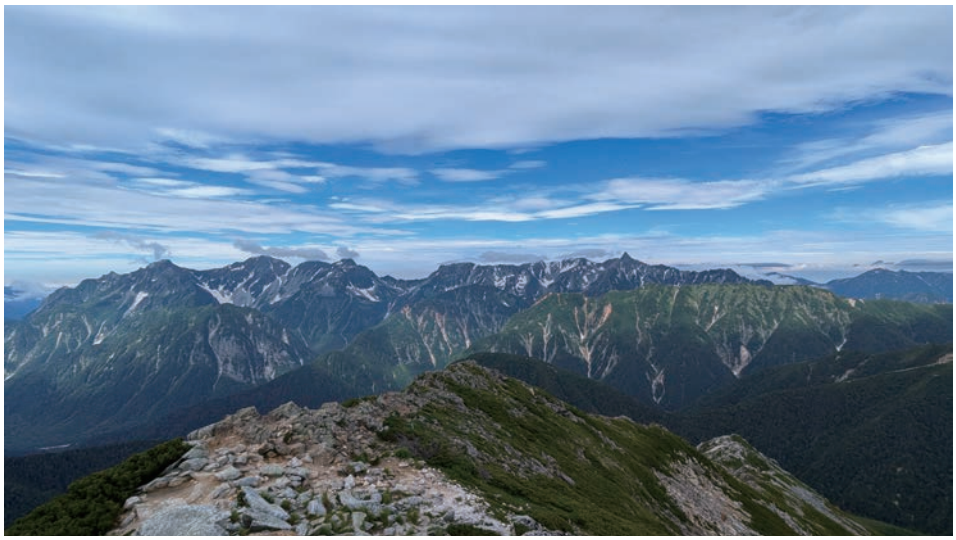

Fig.1 Japan is a biodiversity hotspot but faces high climate velocities (Photographed by I-Ching Chen at Mount J nen)

Fig. 2 Island climate velocities are higher than those in continental mountain regions, threatening biodiversity (Photographed by I-Ching Chen at Orchid Island)

Fig. 3 Alaska mountain regions are also classified as high-risk areas for climate change (Photographed by Jonathan Lenoir at Chugach National Forest, South Alaska)

仿生視覺系統的創新突破：鈦礦量子點光學神經形態突觸元件

李亞儒，教授
智慧半導體及永續製造學院 / 關鍵材料學位學程

李亞儒博士目前服務於國立成功大學智慧半導體及永續製造學院的關鍵材料學位學程，擔任教授兼任副主任一職。在國科會多年研究經費支持下，持續進行與光電半導體實驗相關之凝態物理研究。近年來研究工作主要集中在鈣鈦礦量子點材料應用，包括在仿生人工突觸與光記憶體元件開發、塔米電漿子共振腔體設計、以及激子 - 極化子的生成與凝聚效應。主要探討光與物質間的物理耦合關聯性，並用於調控、提升或製作多功能之新穎光電元件。

人的眼睛作為光的感知器官，能夠為大腦提供關鍵的視覺資訊，並即時重建所見景物的形貌。外界影像資訊首先透過視網膜感知光線，轉化為神經訊號，再經由神經傳遞至大腦皮層進行運算處理與儲存，進而形成人類的視覺記憶。近年來，仿生視覺系統的研究蓬勃發展，並取得了顯著進展。這些研究主要著重於利用影像感測器實現圖像感知功能。然而，在缺乏外部影像刺激的情況下，能夠有效保留或記憶已偵測影像資訊的技術仍相對稀少。為解決此問題，成功大學智慧半導體及永續製造學院的李亞儒與呂欽山教授，聯同光電系許進恭教授及韓國崇實大學的 Hongseok Oh 教授，組成跨國研究團隊，成功開發出一種基於全無機鈣鈦礦量子點的光學神經形態突觸元件。此元件能高度整合感測、記憶與運算功能，為鄰近感測計算技術的發展開啟全新篇章。該研究成果已刊登於國際頂尖期刊《先進科學（Advanced Science）》上。

不同於以往的研究，該團隊不僅在單一元件中實現了影像感測與視覺記憶功能，更成功克服兩種材料系統製程整合的複雜挑戰。由於材料組成與製程結構的高度一致性，這項架構展現出卓越的整合性，能輕鬆製作元件陣列，有效結合影像感測與視覺記憶儲

存功能，並具備低功耗、高效能與成本低等多項優勢。此研發成果預期可廣泛應用於自駕車導航、智慧製造與醫療影像分析等高效彩色影像處理領域，為人工智慧的應用開闢新視野。此外，該技術也可透過同步檢測光子能量，實現即時偵測與感知功能，其非接觸式的光學編碼系統更可應用於目前熱門的矽光子技術。

李亞儒指出，2024 年諾貝爾物理學獎授予約翰 ・ 霍普菲爾德（John J. Hopfield）與傑弗里 ・ 辛頓（Geoffrey E. Hinton），以表彰他們在推動人工神經網路發展上的卓越貢獻，奠定了現代機器學習的基礎。隨著半導體元件日益仿生化，未來科技發展勢必將持續朝此方向邁進。

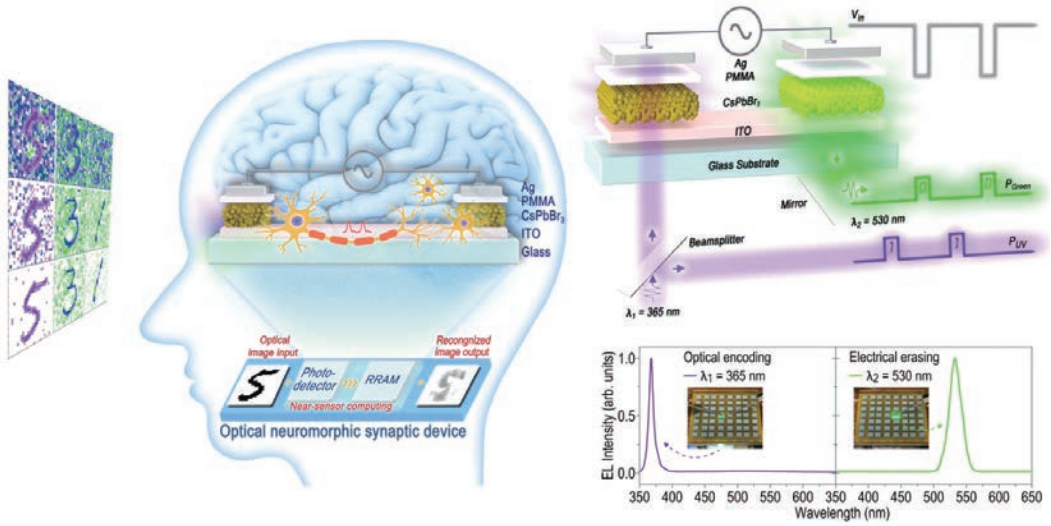

圖 1 （左圖）顯示溴化銫鉛量子點光學仿生神經形態突觸元件的結構及其模擬人類視覺系統運作的示意圖。（右圖）則展示該仿生元件進行光學資訊檢索的運作方式。在左側單元，透過紫外光的照射啟動記憶化過程；而在右側單元，電抹除過程則伴隨綠光的輻射。透過同步檢測紫外光與綠光的光子能量，可以區分出「寫入」和「抹除」兩種編碼狀態。（Adv. Sci. 2025, 12, 2409933）

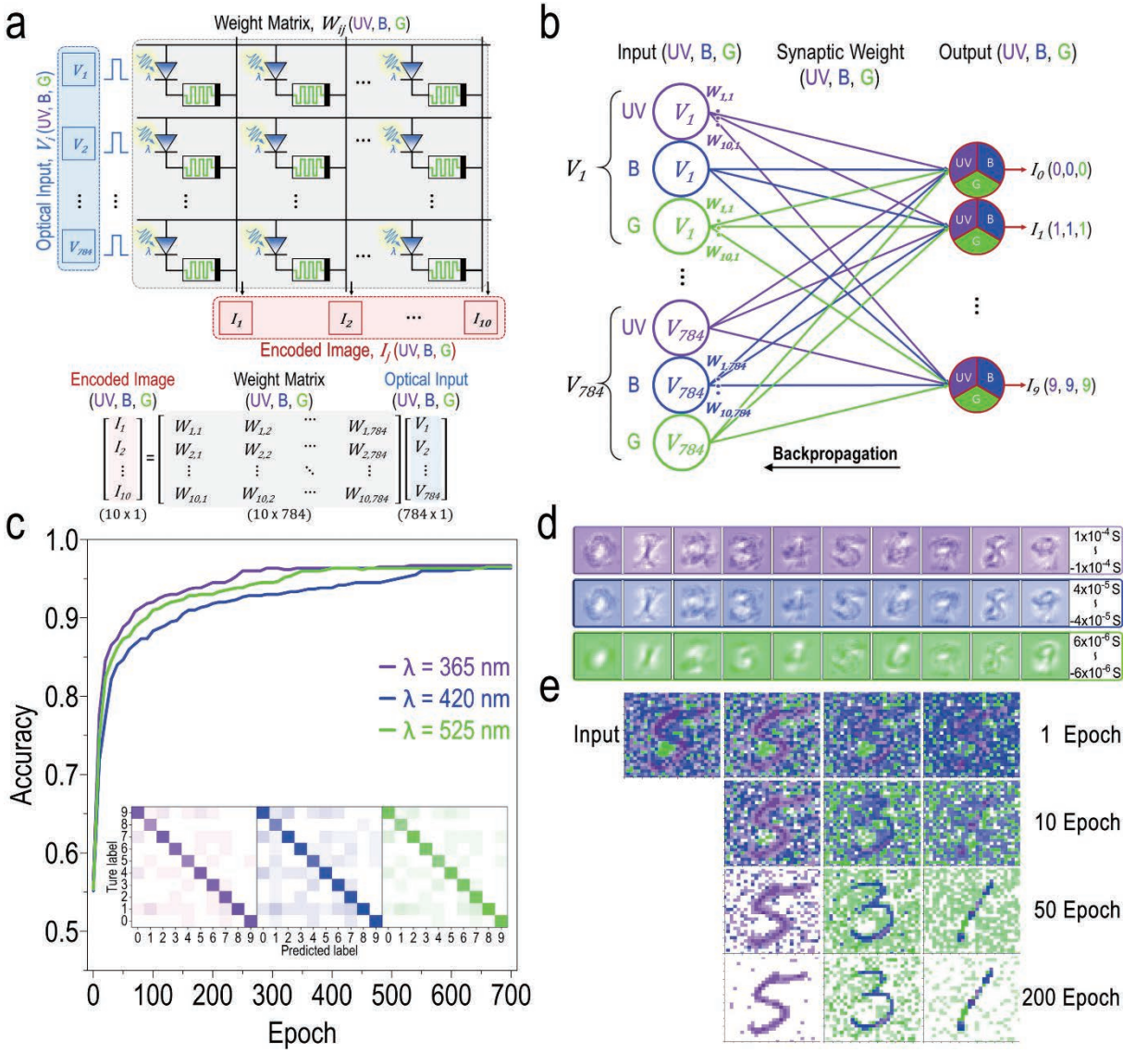

圖 2 顯示利用溴化鉍鉛量子點光學仿生神經形態突觸元件陣列結構，進行彩色及混色影像辨識。經過多次訓練回合後，元件突觸權重達到最佳化，甚至在背景雜訊干擾的情況下，仍能有效鑑別不同顏色的數字。

All-inorganic perovskite quantum dots: a fundamental building block for optical neuromorphic synapse devices

Ya-Ju Lee, Professor
Program on Key Materials, Academy of Innovative Semiconductor / Sustainable Manufacturing (AISSM)

Dr. Ya-Ju Lee is a professor and deputy director of the Program on Key Materials at the Academy of Innovative Semiconductor and Sustainable Manufacturing (AISSM) at National Cheng Kung University. With years of research funding from the National Science and Technology Council (NSC), he has been deeply engaged in condensed matter physics, specializing in optoelectronic semiconductor experiments. In recent years, his research has centered on the applications of perovskite quantum dot materials. His work encompasses the development of biomimetic artificial synapses and optoelectronic memory devices, the design of Tamm plasmonic resonance cavities, and the study of exciton-polariton generation and condensation effects. His primary focus is on exploring the physical coupling interactions between light and matter, utilizing these principles to regulate, enhance, and develop innovative multifunctional optoelectronic devices.

The human eye, as the organ responsible for light perception, plays a crucial role in providing the brain with essential visual information and rapidly reconstructing the appearance of observed scenes. External images are first detected by the retina, where light is converted into neural signals. These signals are then transmitted to the cerebral cortex for processing and storage, ultimately forming visual memory. In recent years, research on bio-inspired visual systems has progressed rapidly, yielding remarkable achievements. Most of these studies focus on utilizing image sensors to mimic the functions of human image perception. However, technologies capable of simultaneously retaining or storing visual information remain relatively underdeveloped.

To address this issue, Professors Ya-Ju Lee and Chin-Shan Lue from the College of Intelligent Semiconductor and Sustainable Manufacturing at National Cheng Kung

University, in collaboration with Professor Jinn-Kong Sheu from the Department of Photonics and Professor Hongseok Oh from Soongsil University in South Korea, formed an international research team. Together, they successfully developed an optical neuromorphic synaptic device based on all-inorganic perovskite quantum dots. This groundbreaking device integrates sensing, memory, and computing functions, representing a significant milestone in the development of near-sensor computing technologies. Their research findings have been published in the prestigious international journal “Advanced Science”.

Unlike previous studies, this research not only achieved the integration of image sensing and visual memory within a single device but also overcame the technical challenges of combining two distinct material systems. This innovation allows for the direct fabrication of device arrays that seamlessly integrate image sensing with visual memory storage. Such a technological breakthrough holds immense potential for applications in high-efficiency color image processing, including autonomous vehicle navigation, smart manufacturing, and medical image analysis, thereby opening new horizons for artificial intelligence. Furthermore, the technology enables real-time detection and perception through the synchronized detection of photon energy. Its non-contact optical encoding system also shows great promise in the rapidly expanding field of silicon photonics.

Professor Ya-Ju Lee noted that the 2024 Nobel Prize in Physics was awarded to John J. Hopfield and Geoffrey E. Hinton for their pioneering contributions to the development

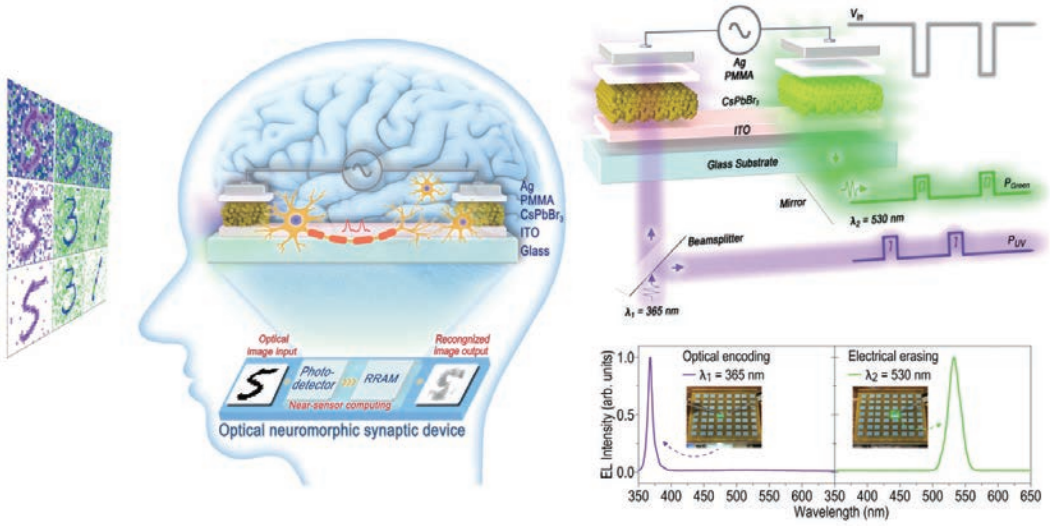

Fig. 1 (left) depicts the structure of the $CsPbBr_3$ QD-based synaptic device, along with a schematic illustrating its operation, which emulates the human visual system. The right panel demonstrates the device's functionality in optical information retrieval. In the left unit, memory programming is triggered by ultraviolet (UV) light irradiation, whereas in the right unit, the erasing process accompanying occurs with green light emission. By synchronously detecting the photon energies of UV and green light, our device can distinguish between the "write" and "erase" encoded states without using the traditional electrical probing method.

of artificial neural networks, which laid the foundation for modern machine learning. As semiconductor devices continue to evolve towards biomimetic designs, future technological advancements are expected to follow this transformative trajectory.

Journal Paper

All-Inorganic Perovskite Quantum-Dot Optical Neuromorphic Synapses for Near-Sensor Colored Image Recognition /Advanced Science /2198-3844/ 16 Dec. 2024

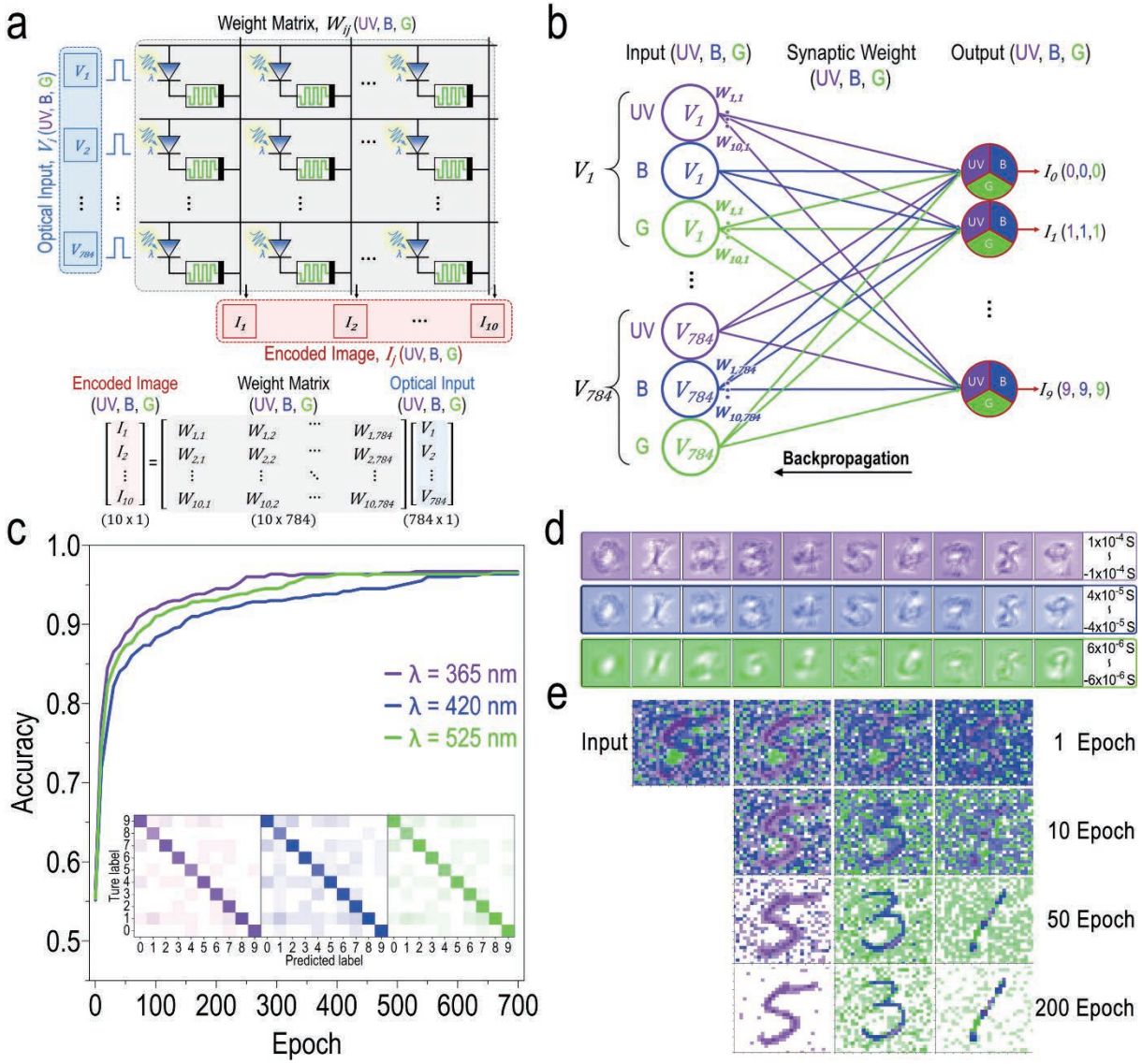

Fig. 2 illustrates the use of our CsPbBrs QD-based neuromorphic synaptic device array for recognizing color and mixed-color images. After extensive training to optimize the synaptic weight distribution, the device accurately identifies different color values, such as green 1, blue 3, and purple 5, even amidst background noise.

解鎖言語的秘密：結合大型語言模型與口語特徵應用於早期阿茲海默症偵測

張亞寧，助理教授
敏求智慧運算學院

大腦與語言運算實驗室

我們的實驗室致力於連結大腦、認知科學和人工智慧的研究，範圍從基礎的大腦和認知功能到人工智慧的應用。透過運算技術，我們研究典型和受損語言處理、語言發展的機制，並構建心理語言學資料庫。與工程和電腦科學家合作，我們開發受大腦啟發的運算裝置，並運用人工智慧方法提升運動遊戲的效能和賽事觀賞體驗。除此之外，在健康醫療，我們運用自然語言處理、深度學習和大型語言模型，發展數位語言生物特徵，自動化早期檢測和神經退化疾病（如：阿茲海默症）和心理健康相關的語言障礙。

語言是人類日常生活中一項非常重要的溝通工具。由於我們語言系統的運作是由許多認知功能共同支持，包含記憶、注意力、控制等等功能。一旦任何一個功能有損傷或衰退，將會影響到我們日常生活中的語言使用（Language use）。本研究團隊致力於解鎖言語的秘密，發展語言特徵為新一代數位健康生物指標。特別是，在臨床上，輕微認知功能衰退和阿茲海默症的檢測通常需透過護理人員進行初步認知測驗和影像學掃描等方式，這一過程不僅耗費大量人力，還需要花費大量時間。因此，在初期篩檢階段，極須一種能夠簡化檢測流程並提升效率的方法。由於神經退化疾病也會反應於日常生活中的語言使用，特別是語速、停頓與文字使用的變化，因此而口語交談成為一種簡單且自然的偵測方式。針對這方面的發展，國外雖有相關研究機構和新創公司（e.g. Novoic, acceXible, etc.）投入發展自動化認知檢測系統，但主要以發展西方語系的語言檢測為主，由於語言的差異性，無法直接應用於臺灣的醫療場域。

本研究由敏求智慧運算學院張亞寧教授團隊主導，並與國內知名的醫療專家合作，包含成大醫院神經內科林宙晴醫師、宋碧姍醫師，臺北耕莘醫院的劉議謙醫師和周家如

研究員。此外，我們也連續兩年獲得 Google Research Awards 的研究資助。在 2024 年，團隊獲邀到臺灣 Google 進行交流報告，展現該計畫在醫療應用上的極大潛力。另外，在國際上合作，也獲得國科會臺灣和英國雙方合作交流計畫案的補助，與英國愛丁堡大學發展精準醫療的 Dr Saturnino Luz 合作發展跨語言特徵擷取的阿茲海默症偵測系統。並在 2024 初釋出中文和英文口語資料集，在 Interspeech 的國際會議，舉辦 TAUKADIAL AI 競賽。

我們設計運用大型語言模型，和使用者對談，引導使用者回答日常生活中的問題，例如，請和我聊聊您的家鄉，然後將回答錄音（如圖一），以進行阿茲海默症的早期偵測。具體來說，該系統透過全自動化的方法，蒐集使用者的口語對話，利用自動語音辨識方法，將口語轉換成文字後，進行文字特徵分析。另一方面，也運用深度學習的方式分析語音特徵。透過同時提取文字和語音特徵，分析資料是否與輕微認知功能衰退或阿茲海默症的早期跡象相關，最後輸出圖像化的檢測報告（如圖二），完成自動化的初步檢測。這樣的口語特徵分析可以迅速進行，替代傳統的人力認知測驗，不僅讓使用者不受時間、地點的限制進行檢測，同時亦簡化早期篩檢的流程。

透過蒐集早期阿茲海默症患者、輕度

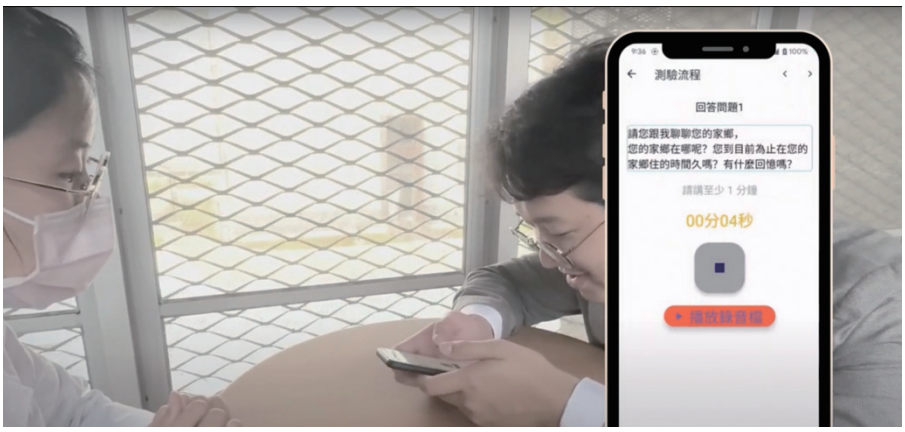

圖 1　系統引導受試者回答問題並錄音

圖 2　雷達圖顯示測驗報告

認知障礙患者、與正常老化族群的自然對話音檔，我們已成功發展系統的評估、測試及整體軟體建置，並已進行多次測試。該系統不僅能識別與早期阿茲海默症相關的語言特徵，更大幅簡化了篩檢過程，能在短時間內提供具參考性的初步檢測結果，成果已陸續發表在國內外的會議和論文期刊。此外，我們已經在耕莘醫院進行實地測試，並獲得正面反饋。

此項技術的發展將大大改善阿茲海默症的早期篩檢過程，並能在時間、地點上提供靈活性，解決傳統檢測過程中人力資源不足的問題。這將有助於推動早期篩檢與及早介入治療的普及，對社會大眾的健康福祉產生深遠的正面影響。未來，我們計畫將此系統部署至數位硬體和機器人等多種平台，使其更具可及性，為更廣泛的使用者群體提供服務。

Unlocking Speech's Secrets: Combining Large Language Models and Speech Features for Early Detection of Alzheimer's Disease

Ya-Ning Chang, Assistant Professor
Miin Wu School of Computing

Computational Brain and Language Laboratory (CBALL)

Our lab focuses on bridging brain, cognitive science and AI, spanning from fundamental brain and cognitive research to practical AI applications. Using computing techniques, we investigate mechanisms in typical and impaired language processing, language development, and construct psycholinguistic databases. In collaboration with engineers and computer scientists, we develop brain-inspired computing devices and employ AI techniques to enhance sports gaming performance and spectator experiences. In addition, in healthcare, we use natural language processing, deep learning and large language models to develop digital speech biomarkers, automate early detection of language impairments related to neurodegenerative diseases (e.g., Alzheimer's diseases) and metal health.

Language is a crucial communication tool in our daily lives. The operation of our language system is supported by many cognitive functions, including memory, attention, and executive control. If any one of these functions is damaged or declines, it will affect our daily language use. Our research team is dedicated to unlocking the secrets of speech and developing speech features as a new generation of digital health biomarkers. Specifically, in clinical settings, the detection of mild cognitive impairment (MCI) and Alzheimer's disease (AD) often requires preliminary cognitive tests and imaging scans conducted by healthcare professionals. This process is not only labour-intensive but also time-consuming. Therefore, in the initial screening stage, a tool that can simplify the detection process and improve efficiency is urgently needed. As neurodegenerative diseases also reflect on daily language use, especially changes

in speech rate, pauses, and word usage, spontaneous speech can become a simple and natural detection method. Regarding this development, although there are relevant research institutions and startups abroad (e.g., Novoic, acceXible, etc.) investing in the development of automated cognitive testing systems, they primarily focus on developing language tests for alphabetic languages. Due to the differences in language, they cannot be directly applied to the medical field in Taiwan.

Our research work is led by Professor Ya-Ning Chang's team from Miin Wu School of Computing, and in collaboration with renowned medical experts in Taiwan, including Dr. Chou-Ching Lin and Dr. Pi-Shan Sung from the Neurology Department at the National Cheng Kung University Hospital in Tainan, as well as Dr. Yi-Chien Liu and Dr. Chia-Ju Chou from Cardinal Tien Hospital in Taipei. In addition, we have received research funding from Google Research Awards for two consecutive years. In 2024, the team was invited to Google Taiwan to present our findings, demonstrating the significant potential of this project for medical applications. Furthermore, in terms of international cooperation, we also received funding from the National Science and Technology Council's Taiwan-UK joint exchange program. We collaborated with Dr. Saturnino Luz, a specialist in precision medicine at the University of Edinburgh, UK, to develop a cross-lingual feature extraction system for AD detection. We also released a Chinese and English spoken language dataset in early 2024 and held the TAUKADIAL AI competition at the Interspeech international conference.

We have designed a system that utilizes large language models (LLMs) to engage in conversation with users, guiding them to answer questions about their daily lives, such as "Tell me about your hometown." The system then records the user's responses (as shown in Fig. 1) to conduct early detection of AD. Specifically, the system uses a fully automated approach to collect users' speech data. Automatic speech recognition (ASR) is employed to convert spoken language into text, followed by text feature analysis. Concurrently, deep learning methods are used to analyze speech features. By

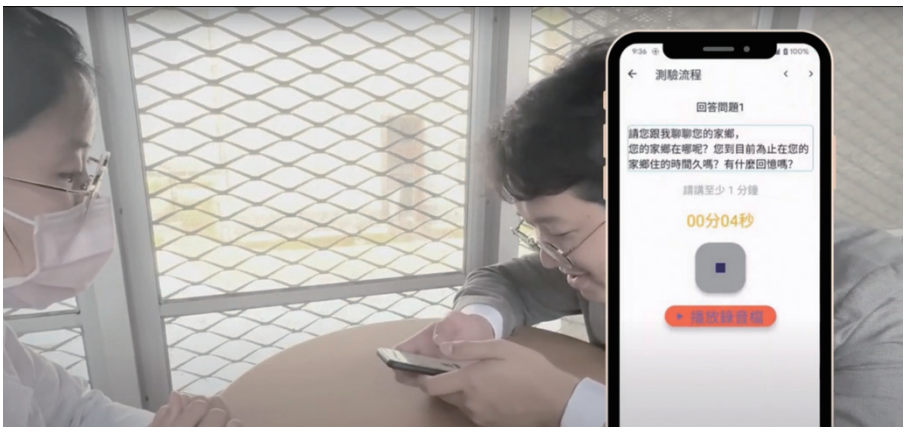

Fig. 1 The system guides the participants to answer questions and records the audio.

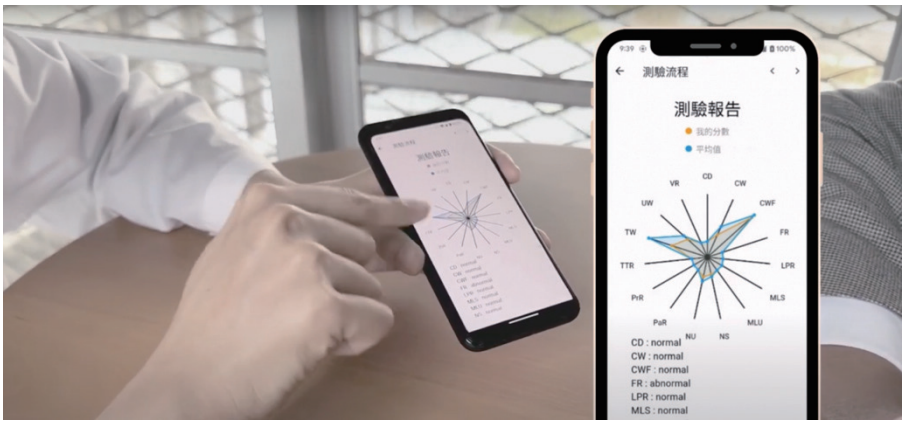

Fig. 2. A graphical report generated by the system after analyses.

extracting both linguistic and acoustic features simultaneously, the system analyzes the data to determine if it exhibits early signs of MCI or AD. Finally, a graphical detection report is generated (as shown in Fig. 2), completing the initial automated detection.

By collecting audio recordings of spontaneous speech from patients with early AD, mild cognitive impairment (MCI), and normal aging populations, we have successfully developed the system's evaluation, testing, and overall software. The system has undergone multiple rounds of testing and has proven to identify linguistic features associated with early AD. It significantly simplifies the screening process, providing timely, reference-worthy preliminary results. The outcome from our research work has been gradually published in domestic and international conferences and journals. Furthermore, we have conducted field tests at the Cardinal Tien Hospital and received positive feedback.

The development of this technology will greatly improve the early screening process for MCI and AD, offering flexibility in terms of time and location, and addressing the manpower shortage that often arises in traditional detection methods. This will facilitate the widespread adoption of early screening, which allows more patients to receive timely interventions and treatments. This system thereby has a significant impact on overall health and well-being in the future. Subsequently, we also plan to deploy this system on various platforms such as edge devices and robots, enhancing its accessibility and providing service to a wider user base.

Journal Paper

1.Screening for Early Alzheimer's Disease: Enhancing Diagnosis with Linguistic Features and Biomarkers / Frontiers in Aging Neuroscience/ 1663-4365 / September 2024

2.Using network analysis to differentiate mild cognitive impairment from healthy individuals/ Architecture and Mechanisms for Language Processing (AMLaP) Conference/ --/June 2024

3.Connected Speech-Based Cognitive Assessment in English and Chinese/ Interspeech Conference/ --/May 2024

4.Exploring an Audio-based Approach for Early Detection of Alzheimer's Disease using

Chinese Speech Data/ Alzheimer's Association International Conference/ --/ April 2024

5.Contrasting Manual and Automatic Approaches for Extracting Linguistic Features in Predicting Alzheimer's Disease through Chinese Speech/ Alzheimer's Association International Conference/ --/ April 2024

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