THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

PolyImpact

Volume III

PolyU Inventions and Innovations that Benefit the World

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MESSAGE FROM THE PRESIDENT

VISIONARY SOLUTIONS AND INNOVATIONS: ANOTHER YEAR OF IMPACT

I am delighted to introduce the third volume of ***PolyImpact***, in which we once again showcase the remarkable achievements of our University community in transforming research excellence into real-world solutions. This annual publication highlights the innovative ways in which the PolyU community is addressing pressing societal challenges through impactful innovations and entrepreneurship.

The year 2024 holds special meaning for PolyU as it marks our 30th anniversary as a university. This institution gained its full university status on 25 November 1994 and has transformed itself over the past three decades into an innovative world-class university known for its academic excellence on the global stage. Indeed, we are now proudly recognised as the 57th best university in the world according to the QS World University Rankings 2025. Furthermore, we have ranked 29th globally in the inaugural Times Education Interdisciplinary Science Rankings 2025. This recent achievement manifests our relentless focus on interdisciplinary research, a cornerstone of PolyU's success.

The PolyU Academy for Interdisciplinary Research (PAIR) plays a crucial role in this regard. PAIR brings together 19 research institutes and research centres to drive interdisciplinary collaboration and innovation in key areas of socioeconomic importance. By combining expertise from different disciplines, PAIR enables us to develop comprehensive solutions to address significant global challenges.

To further amplify the reach and impact of our research, we have embarked on a major initiative to establish Mainland Translational Research Institutes (MTRIs) focused on technology and innovation in various cities across Mainland China. These institutes will conduct high-impact translational research and development work to address the industrial and societal needs of the cities in which they are based. By translating research into practical applications, the MTRIs will integrate PolyU into the national innovation ecosystem, promoting local development and addressing regional challenges. I am pleased to announce that we have signed full agreements for 11 MTRIs, with several of them already launched.

This volume of ***PolyImpact*** showcases ten more pioneering inventions and innovations that make our cities smarter and more sustainable, our industries stronger and more competitive, and our lives healthier and more fulfilling. They include intelligent health monitoring and maintenance systems for long-span bridges; predictive lift and escalator maintenance systems; seamless indoor-outdoor urban navigation systems; advanced research for air quality improvement; novel blockchain algorithms; ultra-precision machining at micrometre and nanometre levels; rechargeable textile-based batteries for wearable devices; as well as cutting-edge solutions to tackle cancer, dementia and osteoarthritis. Our University community continues to push the boundaries of knowledge and create lasting change.

PolyU's commitment to entrepreneurship and knowledge transfer is also evident in our successful track record of supporting start-ups through ***PolyVentures***, our signature start-up ecosystem. We have nurtured numerous innovative ventures, providing them with the resources and mentorship they need to succeed throughout all stages of their development. You will find in this volume some of these start-ups that seek to translate our innovations into impact through commercialisation.

As we look ahead, PolyU remains dedicated to driving progress through innovation. We will continue to invest in our research capabilities, nurture talent, and foster partnerships with industry and government. By working together, we can create a brighter future for Hong Kong, the Nation, and the world in line with our University motto, "To learn and to apply, for the benefit of mankind".

I invite you to explore the compelling stories featured in this volume of ***PolyImpact***. Discover how PolyU's research and innovations are making a tangible difference in people's lives and shaping a more sustainable tomorrow.

Professor Jin-Guang Teng
President
The Hong Kong Polytechnic University

01 FOREVER YOUNG

FOREVER YOUNG

Intelligent health monitoring and maintenance system leverages cutting-edge technologies to keep long-span bridges in peak health efficiently and cost-effectively

Like the human body, infrastructure ages with time and needs regular check-ups. Ageing poses multiple challenges to humans – poor memory, muscle loss, sagging skin and brittle bones. Structures such as bridges also deteriorate over time, undermining their strength and performance. To address this challenge, Prof. Yong XIA, Prof. Songye ZHU, and Dr You DONG, Department of Civil and Environmental Engineering, joined forces with Prof. Jiannong CAO, Department of Computing, to develop an intelligent health monitoring and maintenance system for long-span bridges. The system provides engineers with real-time data on bridge conditions, loads and responses. It also predicts how bridges will age and deteriorate. Based on this information, engineers can develop optimal maintenance strategies to ensure safety while minimising financial, environmental and social costs.

Hong Kong–Zhuhai–Macao Bridge

Ir Prof. Yong XIA

Professor, Department of Civil and Environmental Engineering
Director, Joint Research Centre for Marine Infrastructure

Prof. Xia is a Fellow of The Hong Kong Institution of Engineers (HKIE). He obtained his bachelor's and master's degrees from Huazhong University of Science and Technology, and his PhD from Nanyang Technological University. His major research area is the health monitoring of large-scale structures, including the Tsing Ma Bridge, Stonecutters Bridge, Canton Tower, Shanghai Tower and the Hong Kong–Zhuhai–Macao Bridge. He has co-authored three research books and over 170 journal papers. Prof. Xia has won over 10 national and international awards, including the State Technological Innovation Award, MOE Natural Science Award, and PolyU President's Award.

Ir Prof. Songye ZHU

Associate Head (Research) and Professor, Department of Civil and Environmental Engineering
Associate Director, Research Institute for Climate-Resilient Infrastructure

Prof. Zhu is a Fellow of HKIE and was President of the Hong Kong Section of the American Society of Civil Engineers from 2017 to 2018. He obtained his bachelor's and master's degrees from Tongji University and his PhD from Lehigh University, US. He has authored over 180 peer-reviewed journal papers, and is an editor of Advances in Structural Engineering and an associate editor of the International Journal of Smart and Nano Materials. Prof. Zhu has won numerous awards, such as Takuji Kobori Prize from The International Association for Structural Control and Monitoring.

Dr You DONG

Associate Professor, Department of Civil and Environmental Engineering

Dr Dong obtained his PhD degree in Structural Engineering from Lehigh University. His main research focuses on the risk, resilience, and sustainability-informed design and life-cycle intelligent maintenance of assets under the effects of deterioration and climate change. His research group focuses on physics-guided deep learning, and digital twin-enabled intelligent maintenance. His recent applications include civil infrastructure, energy systems, and interdependent infrastructure systems. He was awarded the IALCCE Junior Award by the International Association for Life-Cycle Civil Engineering (IALCCE), the Young Award for the IABMAS by the International Association for Bridge Maintenance and Safety (IABMAS), etc.

Prof. Jiannong CAO

Dean of Graduate School
Head, College of Undergraduate Research and Innovation
Otto Poon Charitable Foundation Professor in Data Science
Chair Professor of Distributed and Mobile Computing, Department of Computing
Director, Research Institute for Artificial Intelligence of Things
Director, Internet and Mobile Computing Lab
Director, University Research Facility in Big Data Analytics

Prof. Cao's research interests include distributed computing, mobile and wireless networks, big data and AI, and edge computing. He has obtained 13 patents, and published 15 books and over 500 widely-cited papers. He has received many awards for his outstanding research achievements. Prof. Cao is a member of Academia Europaea, a fellow of the Hong Kong Academy of Engineering, a fellow of the Institute of Electrical and Electronics Engineers, a fellow of China Computer Federation and a distinguished member of the Association for Computing Machinery. In 2017, he received the Overseas Outstanding Contribution Award from China Computer Federation.

Doctor of the bridges

Doctors recommend a routine physical exam once a year for those aged 50 or above, or once every three years for those under 30. This is because early diagnosis of sickness allows for prompt action, helping us live longer and healthier lives. The same principle applies to bridges. As vital parts of transportation networks, bridges are the lifelines of a city, and their safety is crucial. But bridges are constantly subject to environmental factors and changing loads that can cause structural damage and even failure. This is why engineers and scientists have developed Structural Health Monitoring (SHM) systems. These systems continuously assess the health of infrastructure, identify and predict potential damage and material degradation, and help extend their service life.

SHM systems are analogous to the human nervous system. In the human body, sensory cells in organs transmit signals to the brain via the nervous system. Similarly, sensors installed throughout the length of a bridge can collect data and send them to a central server via a wireless or wired network for processing and analysis. However, traditional SHM systems are expensive to install and create high computational demand that puts strain on resources. They are also difficult to maintain. To overcome these drawbacks, scholars from the Department of Civil and Environmental Engineering and the Department of Computing have worked closely together to develop an intelligent SHM system.

Footbridge at PolyU

Shenzhen Chuangye Bridge

Decentralised wireless monitoring

Traditional SHM uses a centralised approach, meaning all data from sensors are sent to one central server. However, thousands of sensors collecting data every split second generate a huge volume of data traffic. The scale of a long-span bridge also means that data need to travel a long distance to reach the server. These factors can overwhelm the network and cause delays or even failures. The capacity of the central server also becomes a hurdle that limits scalability.

The team's intelligent SHM system is the first of its kind to apply 5G networks and edge computing to bridge health monitoring. It adopts a decentralised approach – data collected by sensors are partly processed locally and then sent to the central server. This greatly reduces the amount of data transmitted, saving network resources and easing the burden on the server. The system uses AI and machine learning to detect anomalies on edge computing boards. This means data are screened locally and only signs of unusual activities that demand attention are sent to the server to alert users. The use of 5G networks further ensures high-speed data delivery with minimal delay or loss.

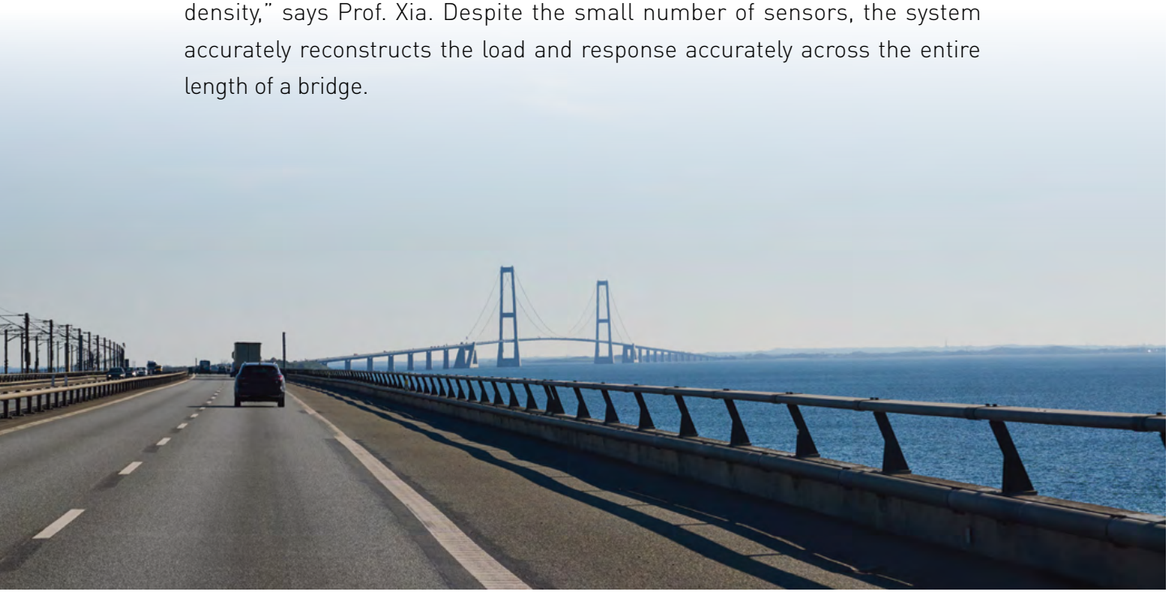
Meanwhile, the machine learning and smart anomaly detection processes need to train a large amount of labelled data, which are not available for a new bridge. "To tackle this, we devised a source-free domain adaptation algorithm. This allows us to transfer models trained on other bridges by using a robust self-training mechanism and a self-knowledge distillation strategy," Prof. Xia explains. "The algorithm means we don't need to build source data from scratch, so the system can be used immediately".

Conditional simulation with sparse sensors

To monitor the condition of bridges, sensors measure the loadings and responses of the structure. These sensors commonly include thermometers and pyranometers to measure or simulate the temperature of the bridge, anemometers to measure wind speed, accelerometers to measure vibrations, strain gauges and displacement transducers to measure deformation or displacement of structures, video cameras to detect vibration using videogrammetry, optical fibre sensors to measure strain and temperature, and global navigation satellite system sensors to measure structural movement.

One limitation of traditional SHM is the limited number of sensors that it can accommodate. As long bridges can span over 20 kilometres, installing sensors along their entire lengths is impractical due to the exorbitant costs and the overwhelming volume of data generated. As a result, a small number of sensors are strategically placed at specific points on a bridge. This limited sensor distribution restricts traditional SHM to rough estimates of load and response between these sensor points.

To accurately reconstruct the load and response profile along an entire bridge, the team developed a conditional simulation method. "Signals from various sensor points are analysed to simulate factors such as wind speed, seismic motion, temperature and traffic load at every point along a bridge using mathematical frameworks such as the coherence model and cross spectral density," says Prof. Xia. Despite the small number of sensors, the system accurately reconstructs the load and response accurately across the entire length of a bridge.



Condition assessment and optimal maintenance strategies

Besides identifying damage and structural issues, data from sensors, inspections, drones and traffic surveillance also help assess and forecast a bridge's structural condition. This information helps create a maintenance plan that balances cost and reliability. "Maintaining long-span bridges is expensive," says Prof. Xia. "For instance, it costs about HK$300 million a year to maintain the Tsing Ma Bridge, and this will increase as the bridge ages. A good maintenance plan can reduce costs and improve safety." SHM systems build an invaluable database revealing not only a bridge's load and response, but also its corrosion rate and its speed of structural deterioration.

The team's highly efficient real-time condition assessment and maintenance system uses an algorithm that is based on the multi-attribute utility theory and the decision making framework to predict degradation and optimise bridge maintenance, cutting material costs by 25% and life-cycle costs by 30%. The system considers environmental, economic and safety metrics – including structural reliability, traffic volume and bridge size – to make optimal maintenance decisions while minimising costs and carbon emissions, and maximising safety.

Smart real-time health monitoring around the clock

The team's intelligent health monitoring system is the first to use 5G networks and edge computing for the SHM of long-span bridges. The system now operates on the world's longest sea-crossing bridge – the Hong Kong–Zhuhai–Macao Bridge. It is also in use on the Shenzhen Chuangye Bridge, and the PolyU campus footbridge linking Block Z and Block X, where it serves as an educational tool to explain SHM to the public, while promoting basic knowledge about bridges, sensors and surveying.

Using forward-thinking and state-of-the-art technology, the interdisciplinary team has successfully overcome the technical challenges of the traditional SHM of bridges, improving efficiency, reliability and network performance. The system ensures public safety while significantly reducing the financial and environmental costs of bridge maintenance. It is an exemplar of advanced technology benefitting people by making their lives easier while achieving long-term sustainability.

DIGGING DEEPER

Intelligent monitoring

With advancements in AI, it is now possible to monitor bridge health in real time. Smart sensors can detect a bridge's response to multiple environmental and climatic factors such as temperature, wind speed, seismic movements, and vehicular loads. The data from the sensors can be processed and analysed in a fraction of a second, allowing engineers to accurately assess the structural condition and material degradation of a bridge. In contrast, traditional approaches rely on rough estimates from numerical models based on assumptions, simple theoretical formulae or small-scale laboratory tests that may differ significantly from real-life situations. This explains why the intelligent health monitoring and maintenance system can achieve unprecedented accuracy on a full-scale bridge.

Intelligent maintenance

Intelligent maintenance refers to using intelligent algorithms to improve the performance, reliability and availability of engineering assets, making maintenance more cost-effective over the life-cycle of an asset. Bridges are important infrastructure assets, and damage can result in major loss of productivity, or even catastrophic consequences. To ensure bridges are in good condition and prevent serious damage or failure, an intelligent system is needed to process the data collected by sensors, and to analyse the cyclical changes of loads and the responses to changing environmental factors. This enables intelligent algorithms to carry out timely preventive maintenance. Besides transmitting, processing and analysing data, the system is also equipped with decision support tools to calculate the best maintenance strategy, considering downtime, cost and carbon emissions. PolyU's intelligent health monitoring and maintenance system uses the multi-attribute utility theory, deep reinforcement learning and a decision-making framework to optimise bridge maintenance, extending lifespan and reducing costs.

02 PULSE OF THE CITY

PolyVentures

PULSE OF THE CITY

Predictive model uses advanced optical fibre sensors and AI to proactively manage lift and escalator maintenance while minimising costs and downtime

Imagine scaling a 100-storey skyscraper without a lift, or navigating Hong Kong's labyrinthine shopping malls without escalators. In this vertical city, where the sky is the limit, these often-overlooked marvels of engineering aren't just conveniences – they're the very arteries that keep the urban heart pumping.

Hong Kong is home to approximately 80,000 lifts and escalators, many of which have been in operation for decades. The sheer scale of this infrastructure presents a unique urban management dilemma. The territory's regulations require annual inspections for lifts and biannual inspections for escalators, a crucial requirement for maintaining public safety. However, a persistent shortage of qualified maintenance professionals means that only 70% to 80% of such infrastructure adheres to these rigorous requirements. This gap between necessity and reality has long been a source of public concern, with residents clamouring for a more reliable solution. To respond to this challenge, Prof. Hwa-yaw TAM and Dr Michael Shun-yee LIU, Department of Electrical and Electronic Engineering, have collaborated closely with the Electrical and Mechanical Services Department of the HKSAR Government. Together, they have developed a ground-breaking solution: the world's first automatic predictive maintenance systems for lifts and escalators, powered by optical fibre technology and AI.

Prof. Hwa-yaw TAM

Chair Professor of Photonics, Department of Electrical and Electronic Engineering
Associate Director, Photonics Research Institute

Prof. Tam, a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) and the Optical Society of America (OSA), is a world-leading researcher in optical fibre sensors, making significant theoretical and experimental contributions to the field. His work has pioneered optical fibre sensor networks that act as sensory nervous systems to monitor, including those for lifts, escalators, railways, and airports, enhancing safety and service quality. His systems monitor hundreds of lifts and escalators and about 90% of metro networks in Hong Kong. These innovations have earned him the prestigious Berthold Leibinger Innovationspreis and three Gold Medals at the International Exhibition of Inventions Geneva.

Co-founder
Avaron Technologies Limited

Avaron
Driving Innovation Technologies for Smart Cities

Ir Dr Michael Shun-yee LIU

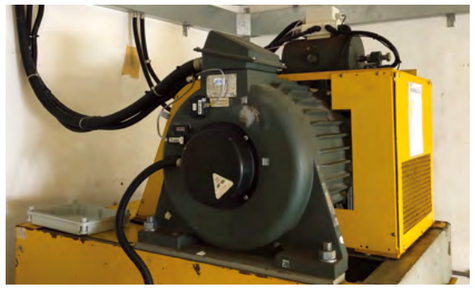
Senior Scientific Officer, Department of Electrical and Electronic Engineering

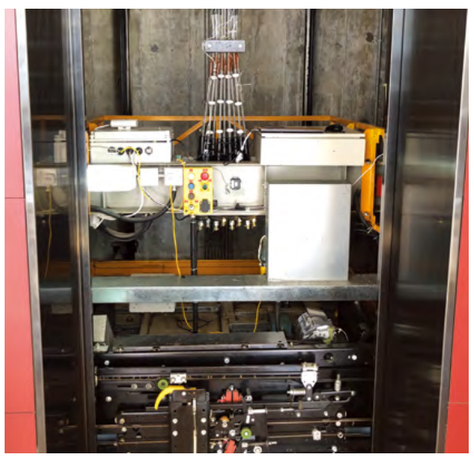
Dr Liu is a Chartered Engineer of the Engineering Council United Kingdom (ECUK) and The Hong Kong Institution of Engineers (HKIE) known for his pioneering railway condition monitoring using fibre-optic sensing technology. He won the Third Prize of the 2014 Berthold Leibinger Innovationspreis and the 2021 PolyU President's Award for his innovations. He has designed and deployed monitoring systems for monorails, light rails, undergrounds, and high-speed rails globally, in countries and regions such as Mainland China, Hong Kong, Singapore, and the Netherlands. His work addresses challenges related to overhead catenary and third-rail systems, as well as rolling stocks and rail tracks, significantly enhancing railway safety and reliability worldwide.

Revolutionising safety

These integrated maintenance systems, known as the Lift Intelligent Monitoring System (LIMS) and the Escalator Intelligent Monitoring System (EIMS), are a series of advanced sensors that work tirelessly to detect potential malfunctions, ensuring the safety and efficiency of vertical transportation.

For lifts, the LIMS uses cameras to analyse the vertical distance between the lift car floor and the hoistway door, preventing passengers from tripping over out-of-level sills. Meanwhile, AI and image processors continuously analyse physical and mechanical data, alerting operators in real time to issues such as malfunctioning lift doors or abnormal vibrations. When potential hazards are identified, warnings are promptly sent to the control panel, allowing for immediate action. For escalators, the EIMS takes centre stage. This system detects speed discrepancies between the handrail and the escalator steps, monitors the wear and tear of escalator rollers (components that support the steps), and even identifies foreign objects striking the comb plate, where the moving steps meet the stationary floor plate. Together, the EIMS and the LIMS form a comprehensive safety net for vertical transportation.

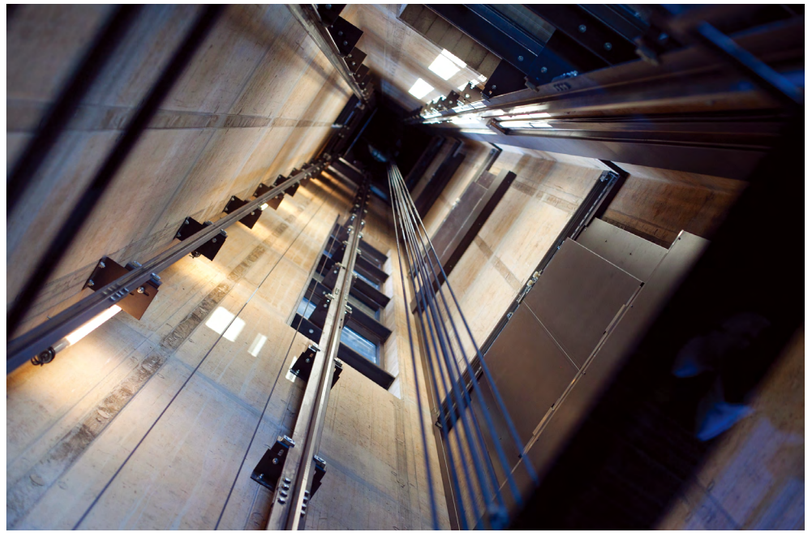




Power of Fibre Bragg Grating sensors

At the heart of both predictive maintenance systems lies a revolutionary technology: Fibre Bragg Grating (FBG) sensors – special optical sensors that can detect tiny changes in their environment, such as vibrations or strain. Think of them as incredibly sensitive 'ears' that can listen to the 'heartbeat' of lifts and escalators. "In an escalator, for example, there can be up to 100 rollers," explains Prof. Tam. "Normal wear and tear can lead to cracks or missing chunks on the surface, compromising their function. Some damage may be hidden under lubricant or paint, invisible to the naked eye. That's when FBG sensors are invaluable."

The system works by recognising that each part of a lift or escalator has its own unique 'vibration signature' when functioning properly. When a part starts to wear out or becomes damaged, its vibration changes – much like a change in its 'heartbeat'. The FBG sensors detect these subtle changes, allowing maintenance teams to be alerted before a breakdown occurs. For escalators, the system's capabilities extend even further. The EIMS can detect when foreign objects such as coins or screws hit the comb plate, with each object creating a unique vibration pattern. In lifts, similar sensors monitor the health of suspension ropes and bearings, and even constantly check rope tension to ensure optimal performance.



To enhance the precision of the EIMS, each roller in an escalator is tagged with a tiny radio-frequency identification chip. This innovation enables the system to pinpoint exactly which roller needs attention, making maintenance more efficient and targeted than ever before. "It's like giving lifts and escalators a comprehensive health monitoring system," Prof. Tam adds. "We can now predict when a part will fail and replace it before it causes any problems. This predictive capability translates into fewer breakdowns, reduced downtime, and ultimately safer rides for everyone using these vertical transportation systems."

Predictive maintenance

To enable remote management, Prof. Tam and Dr Liu designed a user-friendly smartphone app. This displays a health index based on real-time data collected by the sensors, using colour-coded indicators for overall health and individual component conditions – green for healthy, yellow for deteriorating, and red for poor. This visual representation allows maintenance personnel to quickly assess the status of each system and prioritise their tasks.

A key advantage of both predictive maintenance systems is their ability to learn and improve over time. By leveraging big data analytics and machine learning, the LIMS and the EIMS can predict future degradation and failure with increasing accuracy. The intelligent escalator comb plate equipped with FBG sensors, for example, can predict faults with a remarkable 95% accuracy.

This predictive capability translates into tangible benefits for both users and owners of lifts and escalators. It allows for optimal maintenance scheduling, minimises service disruptions, extends equipment lifespans, and significantly reduces operational costs.

From research to reality

The impact of this technology is already being felt across Hong Kong. Through Avaron Technologies Limited, a company co-founded by Prof. Tam and other PolyU alumni, the LIMS and the i-DEMS (EIMS) have been installed on more than 130 lifts and escalators throughout the territory including those in MTR stations, commercial complexes and the iconic Central–Mid-Levels escalator. Their success has not only made vertical transportation safer and more reliable but has also set a new standard for urban infrastructure management.

As cities continue to grow vertically, the importance of safe, efficient vertical mobility cannot be overstated. The benefits of intelligent lift and escalator monitoring systems are multifaceted and far-reaching. For city dwellers, such technology improves safety and reliability in their daily vertical journeys. Building owners benefit from reduced maintenance costs, extended equipment lifespans, and improved budget control. Urban planners now have a new tool to enhance the efficient and resilience of a city. It's a glimpse into a future where our cities are not just taller, but smarter, safer and more sustainable. In this vertical future, the work of Prof. Tam and Dr Liu ensures that our urban arteries will remain healthy, efficient and ready to carry us to new heights.

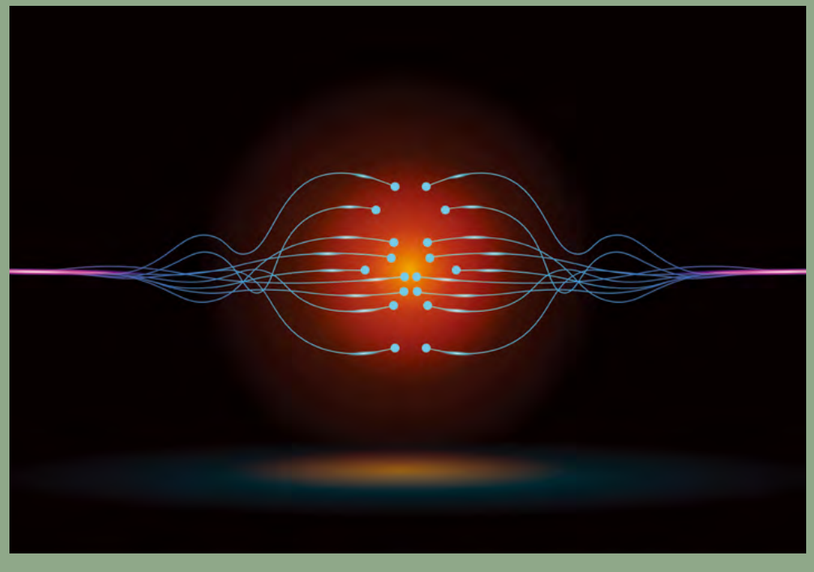
DIGGING DEEPER

Condition-based maintenance

Condition-based maintenance (CBM) monitors the real-time condition of lifts and escalators based on the simple principle of "Do what is needed, not what is scheduled". CBM is more cost-effective and efficient than time-based maintenance, which is prone to over-maintenance, and unnecessarily wastes manpower and resources. Prof. Tam and Dr Liu's innovative approach uses cutting-edge technologies, such as optical fibre sensors and AI, to collect real-time data on the health condition of lifts and escalators. This enables the status and performance of critical components to be continuously monitored. By performing maintenance only when specific indicators show compromised performance, CBM optimises resources, time and costs for maintenance, resulting in smarter and safer lifts and escalators. The team also goes one step further by including predictive functions. These enable worn-out parts and ageing components to be replaced before they fail, minimising unscheduled downtime and service disruptions.

Sensor fusion

Sensor fusion refers to combining data from multiple sensor types to fully grasp a system's condition. In lift and escalator monitoring, one component of the sensor suite is FBG accelerometers, a type of sensor used to measure vibration. Prof. Tam and Dr Liu installed a series of FBG sensors along a single fibre optic cable to measure variables such as temperature, humidity, displacement, tilt and electrical signatures using a single laser beam. These sensors connect to transducers that convert changes in these variables into wavelength shifts in the FBG sensors. Each FBG sensor reflects a specific wavelength of light, while letting other wavelengths pass through. By measuring wavelength shifts, data can be collected from each FBG sensor. The collected data allow the system to develop a holistic view of the equipment's health. This helps identify complex problems that may not be obvious from a single sensor type, further improving the accuracy and reliability of predictive maintenance.



03 ON THE BUTTON

ON THE BUTTON

Seamless indoor-outdoor urban navigation system enables accurate horizontal and vertical positioning for smartphone users, as well as for smart city devices

A Wall Street Journal columnist argues that satellite navigation systems are taking the fun out of road travel because we no longer get lost[1]. Yet, most people are apparently happy with not taking an unnecessary detour on the way to their destination. In a survey conducted in the US, 93% of respondents said they relied on GPS to get around[2]. But in densely built-up areas like Central or Mongkok, the accuracy of GPS may be off by more than 100 metres as satellite signals are blocked or bounce off tall buildings. You could end up a whole block from your intended destination.

[1] Cohen, Rich. "What I Learned Getting Lost on America's Backroads." *The Wall Street Journal*. 27 July 2024. Retrieved from https://www.wsj.com/lifestyle/what-i-learned-getting-lost-on-americas-backroads-cefb5886 on 15 September 2024.

[2] "Study Reveals Where Drivers Are Most Reliant on Their GPS." United Tires Library. Last updated on 8 August 2024. Retrieved from https://www.utires.com/articles/where-drivers-need-gps-the-most/ on 15 September 2024.

In most cases, walking or driving a block to find a new restaurant or shop isn't a major problem. However, smart city applications need a far more precise positioning system. For a self-driving car to stay in lane, it must steer within a range of around 10 to 20cm; for a drone to fly safely between densely packed buildings, it needs positioning accuracy of around 30cm. What's more, in a vertical city like Hong Kong, it can also be a struggle to find your destination in massive high-rise complexes with multiple floors. A positioning system that seamlessly connects outdoor satellite navigation with an indoor counterpart is highly desirable. To address this challenge, Prof. Wu CHEN, Department of Land Surveying and Geo-Informatics, led a research team to develop a seamless urban navigation system. Their system, which can achieve horizontal accuracy of within two metres and vertical accuracy of within one metre, is tailor-made to overcome the difficulties of satellite and indoor positioning in urban centres packed with skyscrapers.

Prof. Wu CHEN

Head and Chair Professor of Satellite Navigation, Department of Land Surveying and Geo-Informatics
Associate Director, Research Institute for Artificial Intelligence of Things

Prof. Chen has been actively working on GNSS related research for over 30 years and has worked on a large number of research projects funded by universities, governments, and industries. His research interests include GNSS technologies, seamless indoor/outdoor positioning, performance evaluation of navigation systems, and 3D modelling with low-cost sensors. In recent years, his main research has focused on solving navigation problems in urban environments and urban Positioning, Navigation, and Timing (PNT) infrastructure. He has published over 300 technical papers in different journals and international conferences, and submitted over 30 technical reports to various organisations.

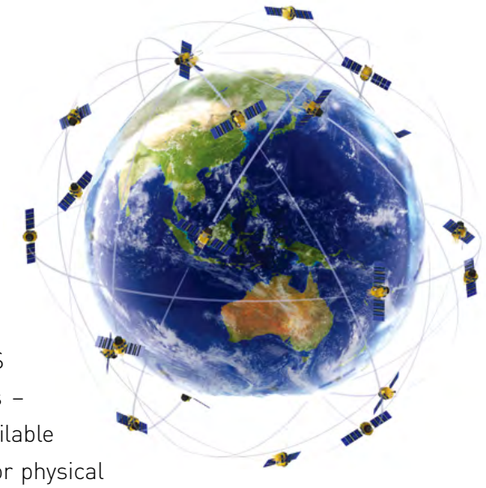
More is more: multiple GNSSs

The team developed a solution that uses multiple Global Navigation Satellite System (GNSS) measurements, 3D city modelling and data gathered from smartphone sensors to improve accuracy. "To determine a position, you need signals from at least four satellites, preferably in direct line of sight," Prof. Chen explains. "But in an urban setting with lots of tall buildings, the range of view may be limited. So, having satellites available across different GNSS platforms is a useful way of boosting the chance of obtaining satellite signals." Currently, there are four major GNSSs: China's BeiDou, the US's GPS, Europe's Galileo, and Russia's GLONASS. The most popular system, GPS, has around 30 satellites. But with access to all four systems, this number jumps to more than 100. "This means you're twice as likely to have satellites in view from any given spot," explains Prof. Chen.

Pinpoint accuracy: differential GNSS (DGNSS)

To further improve the accuracy of primary GNSS systems, an accurately surveyed reference station can be used to correct the discrepancy between a measured position and an actual position. This is called differential GNSS (DGNSS). However, most smartphones don't support DGNSS. To

solve this problem, Prof. Chen and his team proposed a new method that corrects GNSS measurements directly based on a satellite's ID. This enables smartphones to achieve horizontal accuracy within two metres.



However, building reference stations for local DGNSS corrections is not only expensive, but also extremely difficult on a global scale. To address this, the team developed a novel DGNSS platform that uses public precise corrections – highly accurate positioning data that is freely available online to the public, thus eliminating the need for physical reference stations. This is a reliable and affordable way to achieve accurate satellite positioning.

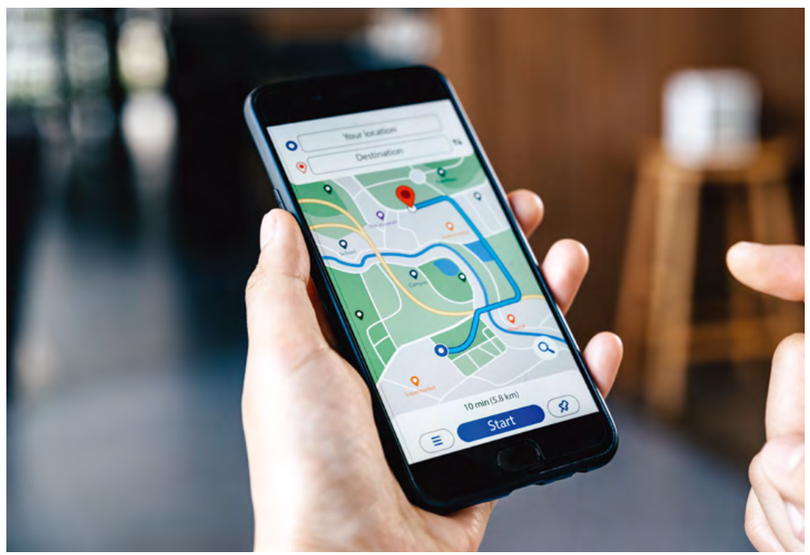
Uniquely urban: multipath mitigation platform

Tall buildings in city centres can give rise to the multipath problem. "The multipath problem arises when not all received signals travel directly from satellites," explains Prof. Chen. "Signals that are reflected or diffracted by a local structure travel a longer path, leading to incorrect measurements. The problem is how to distinguish direct signals from bounced signals." To tackle this challenge, the team cross-referenced satellite positions with location data from inertial measurement unit (IMU) sensors on smartphones, as well as 3D building models that document the shape and height of each building in a city. This helped them identify which satellites could be seen directly from a specific spot, and which signals were reflected or diffracted. Experiments conducted in Wan Chai showed that this method could improve smartphone positioning accuracy from 30 metres to less than 10 metres.

Ever ready: Bluetooth Low Energy (BLE) beacons

Another way to improve positioning accuracy is to use Bluetooth Low Energy (BLE) beacons. These beacons continuously broadcast unique signals that smartphones can detect. When a smartphone is within the range of a beacon, the accurate position of the beacon can help improve satellite positioning. BLE beacons can also detect in which direction a device is moving as it moves from within the range of one beacon to within the range of a neighbouring beacon.

During the recent pandemic, the HKSAR government installed BLE beacons on hundreds of lampposts around the territory to track individuals infected with COVID-19. Now that the pandemic is over, these beacons can be used for urban positioning and navigation, especially in places where GNSS signals are weak or non-existent.



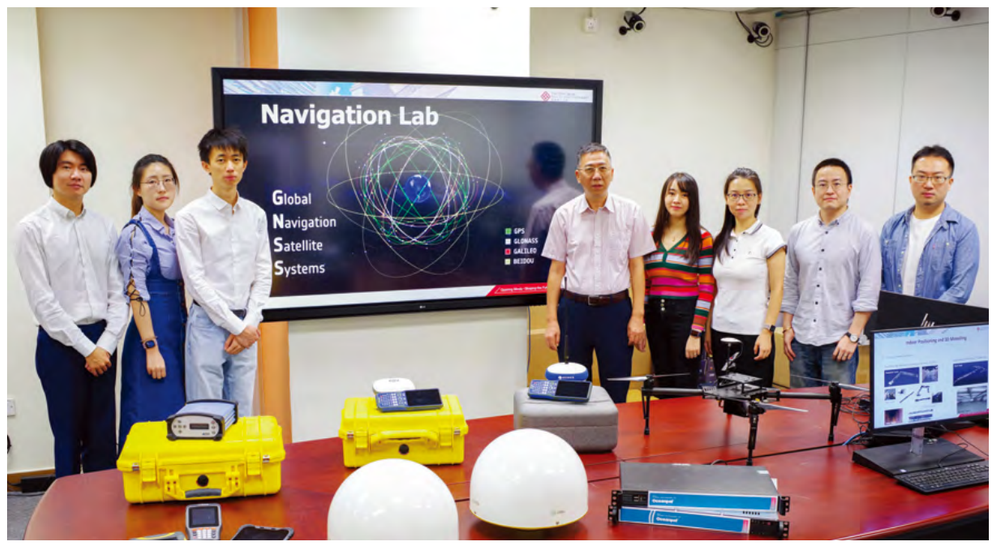
Filling the gaps: AI-powered dead reckoning (DR) model

Dead reckoning (DR) is a way to calculate the current position of a moving object by adding the distance it has travelled to its previously determined position. On smartphones, DR is measured by IMUs and is often used to fill the gaps between GNSS positions in urban settings. However, IMU data on smartphones are of poor quality and can result in major errors. To make IMU data on smartphones more useful, Prof. Chen and his team developed a new DR model based on deep learning. This model is trained with a vast volume of positioning data from smartphones and significantly improves the accuracy of DR calculations in smartphones. When combined with Bluetooth and wi-fi, DR can also be integrated for efficient indoor navigation.

Vertical navigation: smartphone barometers

Some smart city applications, such as drones that monitor the structural health of buildings and surveillance robots that move inside buildings, require height information. To determine on which level a device is located within a building, the team used Hong Kong atmospheric pressure data to calibrate the inaccuracies that are inherent in smartphone barometers. They found that they could determine absolute height to an accuracy of within one metre, making this method useful for indoor navigation.

Prof. Chen's research seamlessly connects precise indoor and outdoor positioning. This not only makes life easier but also paves the way for smart city applications and a brighter future. Each small step that Prof. Chen has made in achieving positioning precision marks a giant leap for mankind.



DIGGING DEEPER

Geoid models

In ancient times, people believed the world was flat. Around 500 BC, the Greek philosopher Pythagoras proposed the idea of a spherical earth, but without any scientific evidence to support his idea. It turns out that Pythagoras' gut feeling was sort of right. In modern times, we've learned that the earth is not perfectly spherical, but rather an irregular ellipsoid. Of course, the earth's surface is not perfectly smooth due to the presence of mountains and valleys. However, for calculating depths and distances, scientists use an imaginary, irregular ellipsoid called a geoid to represent the earth's mean sea level. Prof. Chen and his team achieved centimetre-level accuracy in their Hong Kong geoid model for GNSS heighting, a technique that uses satellites to measure the precise location of a point on earth, including its height above the geoid. This contributes to high-precision surveying of the earth's surface and topographic mapping.

Spatial reference systems (SRS)

To measure an object's spatial position on earth, scientists use a spatial reference system, or SRS. SRSs use analytic geometry to create a coordinate system for the whole planet. At present, thousands of SRSs are in use around the world, each for a specific purpose. These coordinate systems are the foundation for the science and technology of geoinformatics. For example, GPS is an SRS that uses the World Geodetic System 1984 (WGS84) to define locations on earth. In Hong Kong, the local reference frames used for positioning are several metres different from the global reference frames. Prof. Chen and his team are working to update these local reference frames to bring them into line with the global standard.

04 TAKE A DEEP BREATH

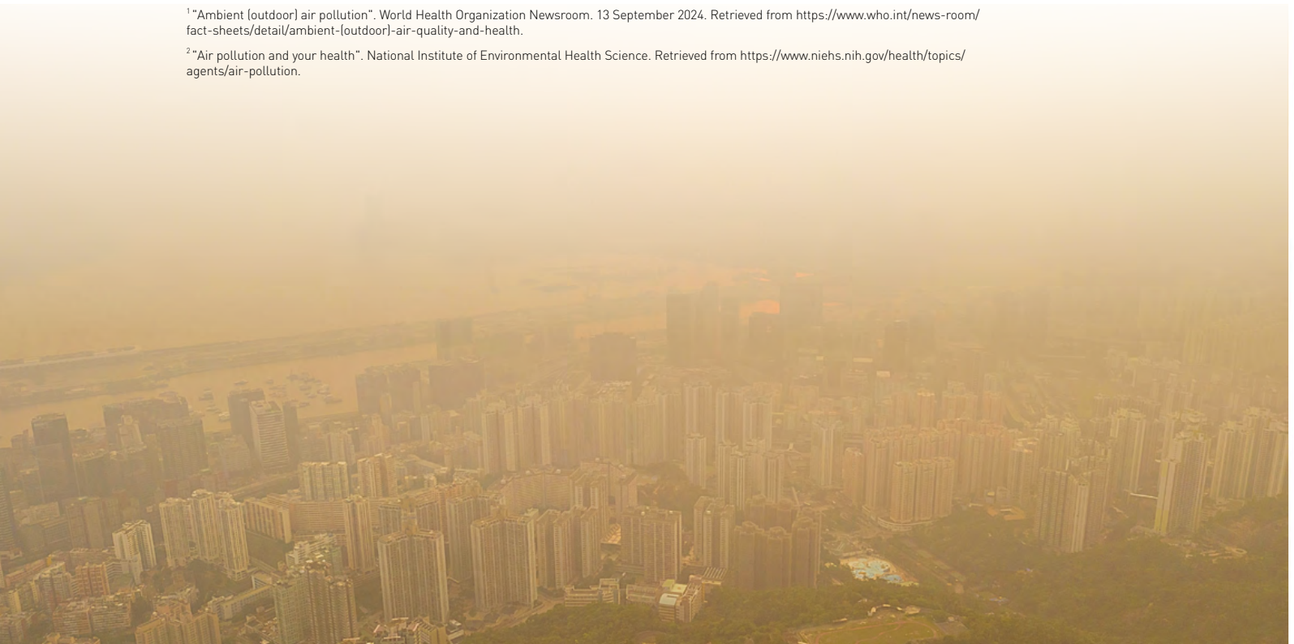
TAKE A DEEP BREATH

Environmental scientists work to improve air quality and public health by studying the composition patterns and health impacts of ozone, nitrogen dioxide and fine particulate matter

On a sunny, windless day, the city is shrouded by a veil of haze with limited visibility. The smell of pollutants is detectable in the air. Air pollution is one of the greatest environmental risks that threatens human health on a global scale. According to the World Health Organization (WHO), in 2019, 99% of the world's population lived in places that failed to meet the standards set in WHO air quality guidelines. In the same year, air pollution was estimated to have caused 4.2 million premature deaths worldwide[1]. Exposure to severe air pollution is associated with elevated risks of cancer, cardiovascular disease, respiratory diseases, diabetes and obesity, as well as reproductive, neurological and immune system disorders[2].

[1] "Ambient (outdoor) air pollution". World Health Organization Newsroom. 13 September 2024. Retrieved from https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

[2] "Air pollution and your health". National Institute of Environmental Health Science. Retrieved from https://www.niehs.nih.gov/health/topics/agents/air-pollution.



Prof. Tao WANG

Chair Professor of Atmospheric Environment, Department of Civil and Environmental Engineering
Associate Director, University Research Facility in Chemical and Environmental Analysis

Prof. Wang conducts research on atmospheric chemistry and air quality. He has coordinated large research projects funded by the Hong Kong Research Grants Council and Environment Conservation Fund and served as the chief scientist for China's National Basic Research Project on acid rain (2005-2010). He has published over 250 papers in international journals and is frequently consulted on air quality issues by the governments of Hong Kong and Mainland China. He received the PolyU President's Awards for Excellent Performance/Achievement in Research (2017/2018), and the Second-class Awards from the Ministry of Education (2009, 2022) and Ministry of Ecology and Environment (2010, 2022).

Ir Prof. Hai GUO

Professor, Department of Civil and Environmental Engineering

Prof. Guo's research involves atmospheric chemistry, organic aerosols, and indoor chemistry. He was one of the first scholars to develop the photochemical trajectory model and the photochemical box model to understand the formation of atmospheric ozone in Asia, and was the first person in Hong Kong to establish a world-class laboratory instrument system for the analysis of trace volatile organic compounds. Since 2020, Prof. Guo has been ranked in the top 2% of highly-cited scientists in meteorology and atmospheric science. He is Chairman (Hong Kong) of the Australia-China Centre for Air Quality Science and Management.

Prof. Shun-cheng LEE

Professor, Department of Civil and Environmental Engineering

Prof. Lee earned his Doctorate in Environmental Sciences from the University of California, Berkeley, US, in 1994. He established Asia's first Laboratory of Carbon Aerosols in 2003. He has led research projects funded by the Hong Kong Green Tech Fund, Research Grants Council, and Environment Conservation Fund. He holds one US patent and three Hong Kong patents. He received the Lyman A. Ripperton Environmental Educator Award (2024) and the Arthur C. Stern Distinguished Paper Award (2019). He has published over 370 research articles with an H-index of 102 and was recognised as a Highly Cited Researcher (2018-2021).

Ir Prof. Xiang-dong LI

Dean of Faculty of Construction and Environment
Ko Jan Ming Professor in Sustainable Urban Development
Chair Professor of Environmental Science and Technology, Department of Civil and Environment Engineering
Director, Research Institute for Sustainable Urban Development
Director, Research Institute for Climate-Resilient Infrastructure

Prof. Li obtained his PhD from Imperial College London, UK. He has published more than 250 papers, mostly in leading international journals. He won the Clair C. Patterson Award (Innovative Breakthrough in Environmental Biogeochemistry) from the Geochemical Society in 2022. He was elected as a Fellow of the Hong Kong Academy of Engineering, and a Geochemistry Fellow of the Geochemical Society and the European Association of Geochemistry. He is the Deputy Editor of *ACS Environmental Au Journal*. He received the PolyU's President's Award for Outstanding Achievement in Research and Scholarly Activities in 2023.

Dr Nathanael Ling JIN

Assistant Professor, Department of Civil and Environmental Engineering
Assistant Professor, Department of Health Technology and Informatics

Dr Jin is engaged in interdisciplinary research at the intersection of environmental chemistry, toxicology, and microbiology, addressing planetary health issues such as air pollution and human health, marine pollution and wildlife health, and environmental transmission of harmful microbes. He has published over 80 papers in journals including *Nature*. In 2022, he was conferred the title of 'Presidential Young Scholar' for his outstanding achievements in research. He received the 2025 '40 Under 40 Award' from the American Academy of Environmental Engineers and Scientists.

Air pollution impacts human health and costs lives. Scientists have been trying to solve this grave challenge, but before they can do this, they must fully understand how different pollutants behave. An air research team from the Department of Civil and Environmental Engineering, including Prof. Tao WANG, Ir Prof. Hai GUO, Prof. Shun-cheng LEE, Ir Prof. Xiangdong LI and Dr Nathanael Ling JIN, have developed advanced mathematical models, leveraged nanotechnologies, and conducted large-scale studies seeking to understand how different chemicals contribute to the formation of major air pollutants. This knowledge will help improve urban air quality by providing a scientific and technical foundation for the formulation of air-pollution control policies.

The good, the bad and the ugly

In 1985, scientists discovered a hole in the earth's ozone layer over Antarctica. By the 1990s, this expanding hole had become a pressing environmental issue. Chlorofluorocarbons (CFCs) – synthetic compounds then commonly used as refrigerants and coolants in refrigerators and air conditioners – were found to be the culprits. CFCs were leaking into the atmosphere, where they were broken down by strong ultraviolet rays, releasing chlorine atoms that reacted with ozone. This ozone in the upper atmosphere, far from the earth's surface, is known as 'good ozone' because it absorbs almost all the

sun's harmful ultraviolet radiation that reaches the earth's atmosphere. Without the ozone layer, the earth would be exposed to destructive levels of this ultraviolet radiation, making it uninhabitable for most life. In 1987, an international agreement was enacted to phase out the use of CFCs and other ozone-depleting substances. Since then, governments have enforced strict regulations, and the ozone hole has gradually been recovering.

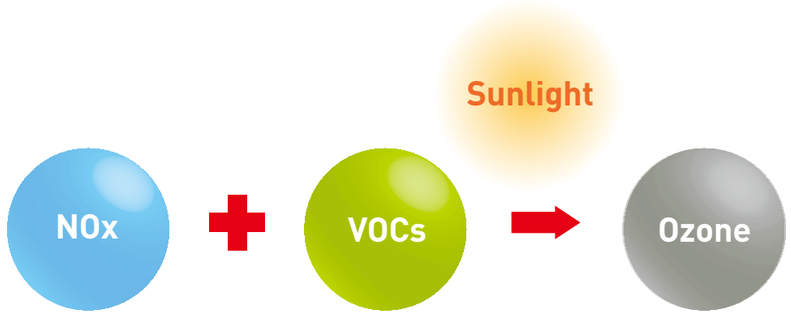
However, ozone is not always desirable. Depending on the altitude at which it occurs, it can also be highly undesirable: ozone in the lower atmosphere and at ground level is an air pollutant that negatively impacts the health of humans, animals and plants. At these lower altitudes, it is sometimes called 'bad ozone'. As it has a similar structure to oxygen, ozone displaces oxygen in the lungs of humans and animals, resulting in respiratory ailments. Ozone is also an irritant that causes eyes to become red and itchy. In vegetation and crops, it causes chlorosis and necrosis, undermining their ability to photosynthesise and thus reducing crop yields.

Tracing the sources

Prof. Wang's interest in ozone pollution dates back to the early 1990s, when he established a background atmospheric monitoring station in Hong Kong – the first of its kind in south China. Using air current data, satellite data, and computer models, Prof. Wang and his team discovered that the increasing ozone pollution in Hong Kong was largely caused by long-range transport, initially from Mainland China and more recently from Southeast Asia.

Oxymoronic equation

Ground-level ozone is produced by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOCs) under sunlight. NOx are mostly produced during the combustion of nitrogen compounds in fuel, such as emissions from cars, power plants and refineries. Over 100 different kinds of VOCs can be produced by biogenic sources such as plants, as well as by anthropogenic sources such as fuel production and combustion. Their reaction can be summarised as:



From this equation, we may expect that higher concentrations of NOx and VOCs in the air lead to higher concentrations of ozone. However, this is not always what happens, and the research team wanted to know why this was the case. Prof. Wang and Prof. Guo thus separately developed the first

observation-based models to determine how each of the key chemicals – NOx and VOCs – affects the formation of ozone in Hong Kong. Prof. Guo's team simultaneously conducted studies in more than 10 other Chinese cities. They also developed analytical techniques for analysing trace-level VOCs in the air – chemicals that are crucial for fully understanding ozone pollution.

To improve air quality in China, in 2013 the Chinese government rolled out its Air Pollution Prevention and Action Plan (the Action Plan). From 2013 to 2017, Prof. Wang and his team investigated how ozone levels changed in response to the lower emissions of air pollutants resulting from the implementation of the Action Plan. Using statistical and computer models, they analysed data from the national environmental monitoring network. Their analysis found that significant declines in ambient concentrations of primary pollutants followed the implementation of the Action Plan. However, these declines were accompanied by higher concentrations of ozone in many urban centres. The team quantified the impact of both emission changes and meteorological conditions on ozone levels and identified several explanations for this unexpected increase in ozone concentrations.

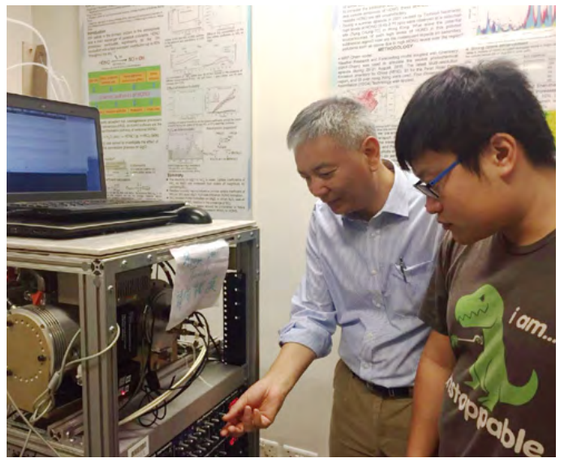
Impact of emission reductions on ozone levels

"First, when there are fewer NOx emissions, the air contains fewer substances to counteract the formation of ozone," explains Prof. Wang. "This can lead to higher ozone concentrations. Second, the Action Plan mostly targeted particulate matter (PM). When fewer particles are suspended in the air, more sunlight reaches the earth's surface. The increased solar radiation triggers the reaction between NOx and VOCs to form ozone," he continues. "Third, PM absorbs certain substances that contribute to the formation of ozone. When there is less PM in the air, fewer of these ozone-forming substances are absorbed, which can lead to increased ozone formation." In the view of the team, controlling the level of VOCs together with NOx and PM would have avoided this unintended consequence of reducing the level of PM.

Influence of meteorological conditions on ozone pollution

Prof. Wang's team also found that variations in chemical conditions alone were not sufficient to explain the observed year-to-year changes in ozone pollution levels. Variations in meteorological conditions also contributed significantly, highlighting the need to consider changes in meteorological conditions when evaluating the efficacy of emission control measures on ozone pollution.

Hok Tsui air monitoring supersite



Addressing global ozone pollution challenges

Meanwhile, Prof. Guo's team posed a related question: how can the growing global challenge of ozone pollution effectively be addressed, particularly in the context of a warming climate and the complexities of surface ozone? "Evidence indicates widespread increases of ozone in the troposphere – the lowest level of the earth's atmosphere," explains Prof. Guo. "Surface ozone, in particular, is chemically complex and difficult to tackle. Despite some past successes, we still need a way to tackle the new challenges of ozone pollution in a warming climate." Prof. Guo's team analysed surface measurement data at 4,300 sites around the world between 2014 and 2019 to highlight the emerging global challenge posed by ozone pollution, especially the unintentional rise in ozone levels due to uncoordinated emissions reductions and the worsening effects of a warming climate.

"Ozone pollution and climate warming are connected in important ways," continues Prof. Guo. "They have similar sources, they interact chemically, and they can harm human health in similar ways. Therefore, we have proposed a new approach that combines efforts to reduce ozone and fine particulate matter. This new approach presents an opportunity to reduce ozone pollution in the troposphere during the upcoming transition to low-carbon emissions."

Thanks to their curiosity and expertise, the air research team has positively impacted the fight against air pollution, improving air quality while protecting the health and the lives of the most vulnerable members of society.

DIGGING DEEPER

Roadside air purifier

Nitrogen dioxide is harmful to humans. It undermines the lungs' defence against bacteria, making us more susceptible to lung infections and aggravating asthma. Vehicles are the main source of roadside nitrogen dioxide pollution. Both the growing number of vehicles overall and the growing number of ageing vehicles are major contributors to nitrogen dioxide pollution, causing a major air quality challenge. In collaboration with the Highways Department and the Environmental Protection Department, Prof. Lee led a research team to develop air purifiers that can be incorporated into smart lampposts to improve roadside air quality. These roadside air purifiers use a combination of physical and chemical processes, along with special nanomaterials, to clean the air. An air blower at the top of the air purifier draws contaminated air from the bottom and pushes it upward through six sets of purification modules. Seven active air purifiers were deployed at PolyU's roadside monitoring station. Within an assessment area of 944 square metres, they removed up to 16% of nitrogen dioxide, up to 10% of nitrogen monoxide, and up to 44% of fine particulate matter measuring 2.5 microns or less ($PM_{2.5}$) in diameter.

Toxic potency-adjusted control of air pollution

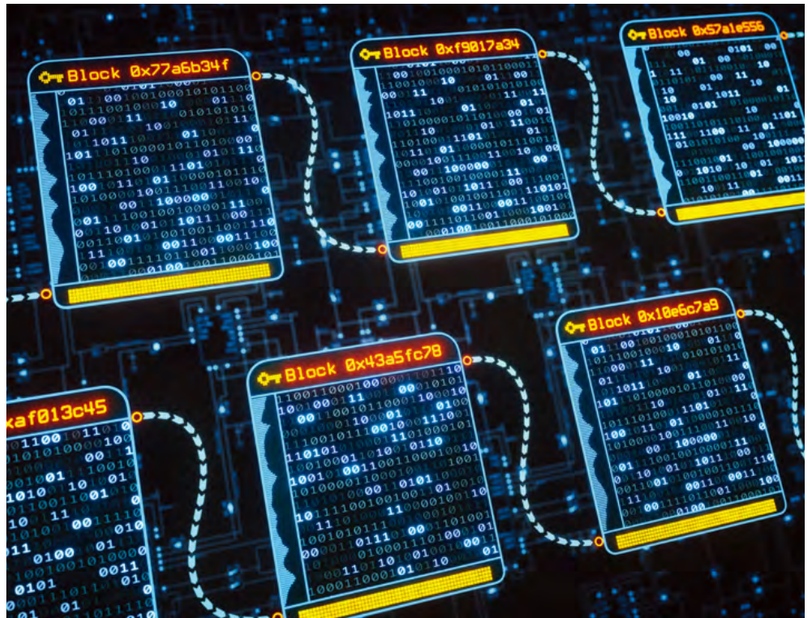
Airborne particulate matter (PM) is a mixture of many chemical compounds that negatively impact human health. For regulatory purposes, these particles are categorised by their diameter. $PM_{2.5}$ fine particles are likely to travel deep into human lung tissue, causing damage and inflammation. Exposure to $PM_{2.5}$ particles is linked to heart disease, bronchitis, other respiratory issues, and even premature death. Prof. Li and Dr Jin, who have been researching $PM_{2.5}$ particles for many years, identified an important but overlooked issue: people exposed to similar mass concentrations of these particles experience varying health impacts. To tackle this neglected issue and improve regulation of $PM_{2.5}$ particles, the team developed a novel mixture–toxicity modelling approach to quantify how exposure to $PM_{2.5}$ particles from different sources results in different toxicity levels among those inhaling them. They found $PM_{2.5}$ particles emitted from the residential sector are about 10 times more toxic than those emitted from coal-fired power plants. This is because the incomplete burning of solid fuels in household stoves generates much higher concentrations of carbonaceous matter. The team suggests adjusting air pollution control regulations based on the toxicity level of the $PM_{2.5}$ particles in question. This means incomplete combustion sources should be controlled more strictly.

05 IN SAFE HANDS

IN SAFE HANDS

Computing experts and researchers write novel algorithms to close security loopholes and manage privacy risks associated with the blockchain ecosystem

By now, investors are no strangers to cryptocurrencies – digital or virtual money that exists on decentralised networks using blockchain technology. Art collectors are also looking at collecting digital art tokenised via a blockchain as non-fungible tokens, better known as NFTs. Another tech buzzword attracting much media attention is Web3, the next-generation decentralised internet that is controlled communally by all participants – again built on blockchain technology. Decentralised finance (or DeFi), an emerging peer-to-peer financial service based on secure distributed ledgers on public blockchains, has also created quite a buzz in both the tech and finance communities. Needless to say, blockchain is the future. So, what exactly is a blockchain?



Public, distributed, decentralised

By definition, a blockchain is a distributed ledger – a database that is shared across a network of computers instead of being stored on a central server. Decentralisation is at the core of this concept. Rather than one big company holding all the sensitive information, the data are spread across the whole network. No one has total control. Instead, all users have collective control. Before a transaction is recorded on the ledger, it must be validated by everyone in the network, and the record cannot be altered retroactively. This

Prof. Allen Man-ho AU

Professor and Associate Head (Research and Development), Department of Computing

Prof. Au obtained his bachelor's and master's degrees from the Chinese University of Hong Kong and his PhD from the University of Wollongong, Australia. Previously, he held a faculty position at The University of Hong Kong. His major research areas are cybersecurity, blockchain, and applied cryptography. Prof. Au has twice won the ZPrize, received the PET Runner-Up Award for privacy research, and was honoured with the 2023 BOCHK Science and Technology Innovation Prize in FinTech.

Prof. Daniel Xiapu LUO

Professor, Department of Computing
Director, Research Centre for Blockchain Technology

Prof. Luo specialises in the security of blockchain and smart contracts, mobile and IoT, software and systems, and networks. His research has earned him 16 best/distinguished paper awards, such as ACM CCS 2024 Distinguished Paper Award, four ACM SIGSOFT Distinguished Paper Awards, Best DeFi Papers Award 2023, Best Paper Award at INFOCOM 2018, etc. He also received the BOCHK Science and Technology Innovation Prize (FinTech). His research has revealed critical vulnerabilities in blockchain, mobile apps, IoT devices, and vehicles, and has been used by industry to detect and analyse malware and cyberattacks.

means you can pay someone digitally without having to keep your personal information on the server of your bank, credit card issuer, or any other payment platform, essentially removing the risk of a data breach. Your payment record (or the payee's proof of ownership of the fund) is permanent and anyone can view it. Overall, blockchain makes the exchanges of value and assets quicker, safer, and less costly.

One way to explain the concept of blockchain is the glass box analogy. Imagine a blockchain as a 24-hour bank with uniquely numbered glass deposit boxes. Everyone coming to the bank can see and verify the contents of each glass box. Anyone can put money in someone else's box if they know the owner's unique number. When a transaction occurs, everyone can see the changes in the contents in the boxes of the parties involved in the transaction. After everyone verifies the new contents of these boxes, the transaction is written in the record. As no one can tamper with the traceable, permanent record, and as the boxes are collectively monitored by everyone, this transparent system significantly lowers the risk of manipulation and fraud.

Mitigating emerging tech risks

But all new technologies come with new risks. Because of their decentralised nature, which makes them almost impossible to hack, blockchains are

supposed to be secure. But despite their supposed security, millions of dollars are lost to crypto scams every year due to security shortfalls hidden in the blockchain ecosystem. To address this challenge, Prof. Allen Man-ho AU, and Prof. Daniel Xiapu LUO, Department of Computing, have developed novel algorithms to protect the privacy of blockchain users, boost the security of secret keys, discover security vulnerabilities in the blockchain ecosystem, and defend against malicious attacks.

Cryptographic foundation

Before a transaction is recorded on a blockchain, it must be verified by all users, a process that can be time-consuming. Privacy is also a concern, as all users can see all the details of a transaction. Prof. Au's team has addressed these concerns by developing an efficient zero-knowledge proof (ZKP) algorithm that accelerates the validation process and prevents the leaking of sensitive data. For example, instead of posting 1,000 transactions on a blockchain and asking users to verify them one by one, a short proof is posted stating that these 1,000 transactions are valid. Users simply need to validate this proof instead of verifying each of the 1,000 transactions. What's more, this short proof does not contain any details of the transactions, thus protecting user privacy.

When managing virtual assets, the security of the secret key is crucial. Prof. Au's team has devised a distributed cryptographic key based on threshold cryptography. The secret key is divided into five parts and stored on five servers. To sign into an account, the user needs three of these five parts. "Even if a hacker manages to breach one server, they can't log into an account without two more parts. The hacker has no idea where the rest of the key is stored, making it a lot harder to steal a secret key," explains Prof. Au. "What's more, as the key is stored across five servers, the user can still retrieve three-fifths of the key from other servers even if one server is down, and so won't be locked out of their account." Threshold cryptography thus not only provides a major boost to secret key security, it also ensures that users can access their assets even if a server fails.

Blockchain ecosystem security

Although blockchain has built-in security features, the blockchain ecosystem is riddled with loopholes and vulnerabilities. Components such as blockchain platforms, smart contracts, third-party services, frontends, and the communication network are all susceptible to cyberattacks. Prof. Luo's team has developed a dual-pronged strategy to comprehensively fortify blockchain ecosystems.

The first prong concentrates on detecting security vulnerabilities, with an intense focus on zero-day vulnerabilities – security flaws that are not yet known and therefore have no existing fix, making them particularly dangerous as they can be exploited by attackers before they can be addressed. These investigations have exposed significant flaws in major blockchain infrastructures. Leading companies and developers have recognised the value of these crucial discoveries and offered bug bounties – financial rewards for reporting security flaws. Prof. Luo's team has also pioneered the development of innovative tools to streamline the detection of vulnerabilities in smart contracts and blockchain platforms. A notable achievement is their creation of the first GPU-based fuzzer for smart contracts – a tool that uses GPUs to test smart contracts for vulnerabilities. This tool can process and test smart contracts ten times faster than existing state-of-the-art techniques.

The second prong of the team's strategy shields blockchain ecosystems from a range of attacks. The team has introduced novel techniques to detect and counter various forms of advanced malware, including malicious smart contracts and apps. These techniques have been adopted by leading IT companies. The team has also designed cutting-edge methods to identify and mitigate different attacks targeting blockchain ecosystems, thereby increasing user protection.

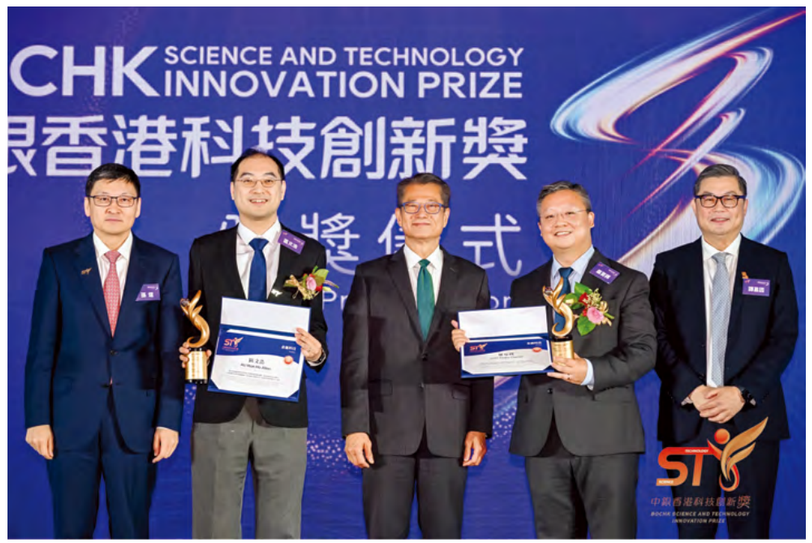
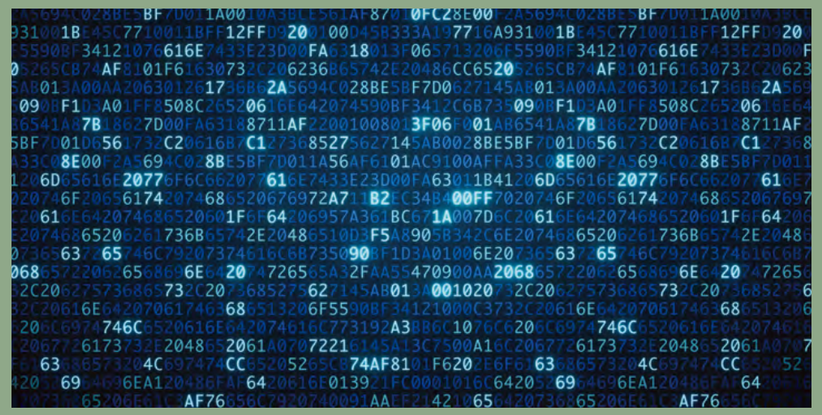


Image courtesy of BOCHK Science and Technology Innovation Prize

Prof. Au and Prof. Luo's teams have received numerous local and international awards. These include the prestigious BOCHK Science and Technology Innovation Prize in FinTech (2023), and the ZPRIZE, which Prof. Au's team has won twice – the only team in Hong Kong to achieve this milestone. In July 2024, an international bank commissioned Prof. Au's team to enhance the privacy of its digital currency system using ZKP technology. The team is also collaborating with a leading telecommunications company to develop its next-generation identity platform. Prof. Luo has made significant contributions to blockchain security by discovering critical vulnerabilities in popular blockchain ecosystems and defending against advanced, stealthy attacks. His findings have been recognised by leading blockchain and IT companies.

Blockchain is a tamper-proof, secure database shared by a network of users. It makes payments and exchanges of value safer, quicker, and less costly. But with potential benefits come potential risks. Reducing the risk of attacks and fraud, and ensuring best practices within the blockchain ecosystem, requires a comprehensive risk management system. Prof. Au and Prof. Luo's research takes us one step closer to a blockchain ecosystem free of malicious attacks and scams, where we can trade value and assets with peace of mind.

DIGGING DEEPER



Zero knowledge proof (ZKP)

Nowadays, we manage our finances online, we file our tax returns online, and we buy and sell our belongings online. However, before we can perform any transaction online, we need to verify our identity. This sometimes involves scanning and uploading our identity documents, such as our passports or identity cards, to an intermediate body or server. But we can't help worrying about our personal information being leaked or our identity being stolen if a server storing such sensitive information is hacked. Zero knowledge proofs (ZKPs) effectively reduce the risk of data breaches by only storing personal information as an electronic certificate on a server, rather than a copy of the identity document itself. Verifiers can securely access and verify the identities of users, but they cannot access their actual data. The owner of the personal information can choose what to include and disclose on the certificate, and the transmission is encrypted with a single-use pre-shared key. This means that even if hackers steal the file, they cannot decrypt it. And if they do manage to decrypt it, they only have a certificate without any sensitive information. However, a key issue with ZKP is its slow proof generation. To overcome this, Prof. Au's team uses distributed computing and a graphics processing unit to speed up the generation of proofs.

Post-quantum cryptography

Quantum computers, built on the principles of quantum mechanics, can solve mathematical problems that are too difficult for classical computers. In 2019, Google claimed its quantum computer needed just 200 seconds to solve a problem that would take the world's fastest supercomputer 10,000 years. In other words, a quantum computer can work 100 million times faster than a classical computer. By drastically shortening the time needed to break encryption algorithms, a quantum computer poses a major threat to public encryption systems if acquired by a malicious actor. Every encryption system can be cracked, given enough time. With a classical computer, a malicious actor may need decades to process the data involved in an encryption. But if large-scale quantum computers exist in the future (experts expect the engineering challenges to be overcome in about two decades), stolen encrypted data can be decrypted easily and efficiently. To address this potential threat, Prof. Au's team has developed cryptographic algorithms that are secure against attacks from both quantum and classical computers. These algorithms are also interoperable with existing communications protocols and networks.

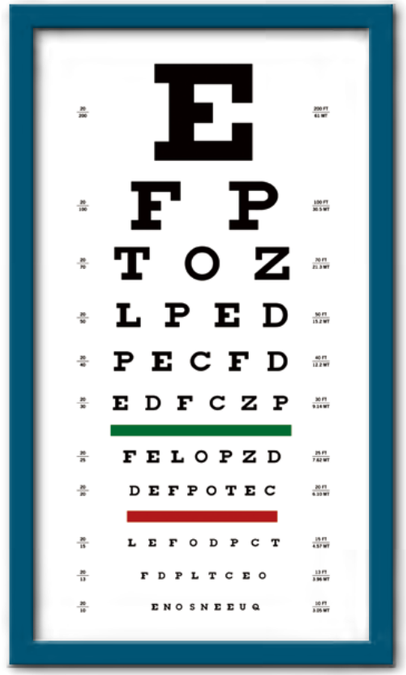
06 SMALL IS POWERFUL

SMALL IS POWERFUL

From myopia control spectacle lenses to nano-polished scalpels, ultra-precision machining enhances our lives, one micrometre or even one nanometre at a time

Myopia, or nearsightedness, occurs when the eyeball is too long relative to the focusing power of the cornea and lens of the eye. It can be corrected either optically with spectacle lenses and contact lenses, or surgically. In the 2010s, a School of Optometry (SO) research team led by Prof. Chi-ho TO, Prof. Carly Siu-yin LAM and Dr Dennis Yan-yin TSE translated their research into the Defocus Incorporated Soft Contact (DISC) lens. This technology was commercialised in 2018 by Vision Science and Technology Co. Ltd (VST), a PolyU start-up co-founded by Prof. To and SO alumnus Mr Jackson LEUNG.

DISC is a multi-zone soft contact lens made up of concentric rings that



alternately project clear images onto the retina, and blurred, out-of-focus (defocused) images in front of the retina. The wearer can see clearly while the defocused image simultaneously sends a signal to the eye to slow down its growth as it tries to shorten the eyeball to focus the defocused image on the retina. In clinical trials, DISC was proven to slow myopia progression by 60% among Hong Kong schoolchildren between the ages of 8 and 13.

Overcoming technical challenges

However, eye health issues prevent some schoolchildren from wearing contact lenses. Some are simply too young to maintain personal hygiene or follow contact lens care and cleaning routines. In response to this challenge, VST has developed a spectacle lens version of the DISC lens. Nevertheless, developing such a lens

Ir Prof. Benny Chi-fai CHEUNG

Chair Professor of Ultra-precision Machining and Metrology, Department of Industrial and Systems Engineering
Director, State Key Laboratory of Ultra-precision Machining Technology (The Hong Kong Polytechnic University)
Director, The Hong Kong Polytechnic University-Wenzhou Technology and Innovation Research Institute

Prof. Cheung is a leading scholar in his pioneering and sustainable research in ultra-precision machining technology and precision metrology. He is a Fellow of the International Academy for Production Engineering (CIRP Fellow), a Fellow of the American Society for Precision Engineering (ASPE Fellow), and a Fellow of The Hong Kong Institution of Engineers (FHKIE). He has received numerous awards including the ASAIHL-Scopus Young Scientist Award, Joseph Whitworth Prize, A M Strickland Prize, IET Innovation Award, Bank of China Hong Kong (BOCHK) Science and Technology Innovation Prize 2023–Advanced Manufacturing, etc.

was not as simple as enlarging the DISC lens to the size of a spectacle lens. Facing a range of technical obstacles, the company collaborated with SO researchers and a team led by Ir Prof. Benny Chi-fai CHEUNG, Chair Professor of Ultra-precision Machining and Metrology, Department of Industrial and Systems Engineering, and Director of the State Key Laboratory of Ultra-precision Machining Technology (The Hong Kong Polytechnic University) (SKL-UPMT).

Producing a spectacle lens equivalent to the DISC lens presented several challenges. "The DISC lens works because it fits snugly on an eyeball and follows the eye's movements. But when used in a spectacle lens, it's difficult to achieve clear vision. Some wearers find that their eyes have trouble adjusting," explains Prof. Cheung. Also, the DISC lens cannot include correction for astigmatism. This was a key challenge that the team had to overcome when developing the spectacle lens version of the DISC lens.

The aesthetics, or the look of the lens, was also important. "Not many schoolchildren would be willing to wear glasses with obvious rings on them", observes Prof. Cheung. "No matter how effective a tool is, it's still useless if no one wants to use it. So, we needed to make the spectacle lens look like those in regular glasses. We also wanted to keep the cost low so that the spectacle lens version would be affordable for more parents."

Smoothness, at a nanometric level

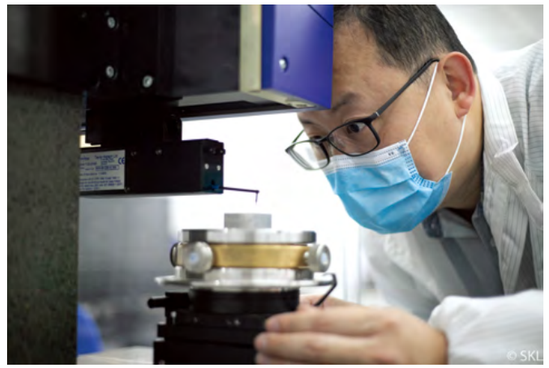
The partnership developed the Novel Nano Multi-ring Defocus Incorporated Spectacle (NMDIS) lens, known commercially as MyoDisc. This lens combines advanced optic design and ultra-precision machining with a unique tangential continuity nano multi-ring structure. "We smoothed out the transitions between the nanometric rings to achieve seamless connections. As a result, the NMDIS lenses look just like those in regular glasses", explains Prof. Cheung. "No existing equipment could measure the power of a spectacle lens across its whole span, so we developed a proprietary defocus measurement method to make sure every point on the lens is optimised optically. This ensures that wearers can adjust to the NMDIS lenses with ease and comfort."

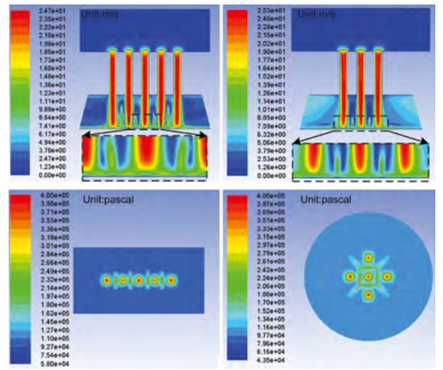
To reduce manufacturing costs, the spectacle lenses are produced by injection moulding instead of machining them individually. However, the ultra-precision moulds for nano rings are still expensive to produce. To cut costs, the team moulds only one side of the lens with nano rings for defocus, while the other side uses a regular mould for correcting astigmatism or myopia, which is much cheaper. This means all prescriptions up to -10.00 only require one ultra-precision mould. VST launched the NMDIS lens in December 2022. As at October 2024, 30,000 pairs have been sold in Mainland China and Hong Kong, helping some 30,000 children combat myopia progression while retaining clear vision.

Pushing the limit

Advanced optics manufacturing technology is just one key research direction that SKL-UPMT is pursuing. The lab is also researching micro and nano machining mechanics, advanced ultra-precision machining technologies and processes, freeform surface metrology, and equipment for use in ultra-precision machining. Specifically, the lab has been developing equipment accessories and ultra-precision manufacturing equipment to meet the needs of scientific research and manufacturing in the age of Industry 4.0 – also known as the Fourth Industrial Revolution. Their innovations include instruments for in-line testing and measurement of products for fully automated production lines. "At SKL-UPMT, we strive to connect the whole industry chain – from design and manufacturing, to marketing and after-sales service," Prof. Cheung says.

The lab has also strengthened the technological innovation cooperation between Mainland China and Hong Kong by setting up branch laboratories in Wenzhou and Shenzhen. Annexed to PolyU-Wenzhou Technology and Innovation Research Institute and PolyU-Shenzhen Industrial Technology and Innovation Research Institute, these branch labs will focus on smart precision manufacturing and AI-enabled quality assurance, and the development of ultra-precision manufacturing and optical inspection equipment, respectively. "For the NMDIS lens, our Wenzhou branch lab will be responsible for precision manufacturing and checking for defects of the lenses, and reconfirming the optical power and exact configuration of the lenses using AI-powered algorithms."

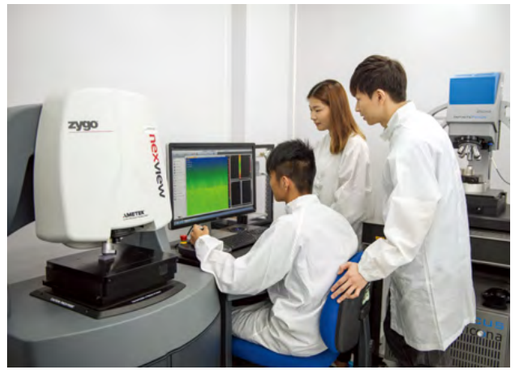




Touchstone for testing products' impact

By collaborating with the SO and industry partners, Prof. Cheung has demonstrated that ultra-precision machining and precision metrology can benefit a wide range of industries. This includes not only tech-centric industries such as aerospace and biomedicine, but those producing also everyday applications such as eyeglasses and self-cleaning mirrors.

"Partnering with industry is crucial for turning our technologies into market-ready products," observes Prof. Cheung. "Ultimately, it's the market that judges the impact of a product, based on how many customers benefit from it, not just our own claims of success." With over 30,000 people already benefitting from the pilot production of the NMDIS lens, Prof. Cheung has successfully showcased the societal impact of ultra-precision machining, while enhancing both the products we use and our daily lives.



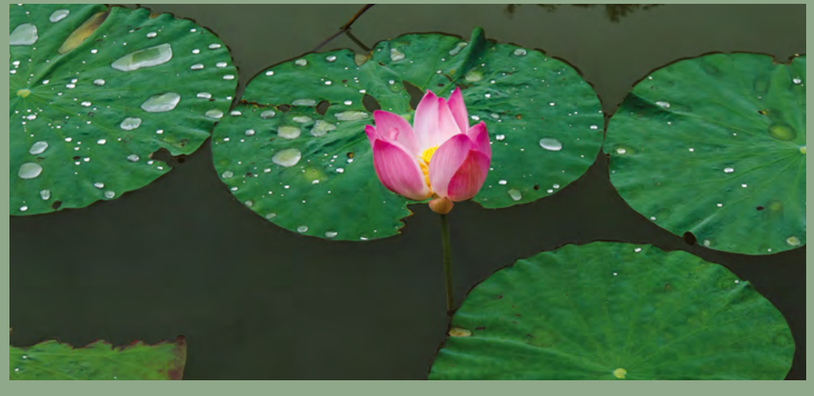
DIGGING DEEPER

Ultra-precision machining

Ultra-precision machining is a cutting-edge advanced manufacturing technology that produces intricate components with highly accurate dimensions and geometries, usually at the sub-micrometre level, which is 1/100 of the diameter of a human hair. This engineering forms the backbone of innovative technologies in aerospace, electronics, automobiles, optics, and biomedical engineering. Prof. Cheung's team aims to achieve smooth and precise surfaces with nanometre-scale surface roughness. Given that a strand of DNA is about two nanometres wide, this means the difference between the 'peaks' and 'valleys' of a surface profile cannot be bigger than a single DNA strand. Using state-of-the-art methods such as diamond turning, micro-milling, micro-grinding, single-point diamond machining, computer controlled ultra-precision polishing, and free-form machining, the team can make precision injection moulds with the tightest tolerances and optical surface quality, achieving roughness values in the micrometre and nanometre range. These moulds are used to produce lenses with micro/nano-structures and shapes that bend light rays exactly as intended. Examples include the NMDIS lens and autostereoscopic displays for electronic devices. The team continues to push the limits of what is technically possible, achieving ever higher levels of precision.

Functional surface

Advances in ultra-precision machining make it possible to create micro- and nano-structured surfaces, which can alter the surface properties of a material and even imbue it with new functions. For example, ultra-precision machining can polish a scalpel blade to such a smooth and precise finish that it minimises surgically-induced tissue trauma, swelling, and scarring, thereby speeding up wound closure and healing. Similarly, artificial joints must be machined within the tightest tolerances to ensure a perfect fit. With nanometric surface roughness, friction between components in artificial joints is minimised, extending their longevity. Micro- and nano-structures also exist in nature, providing a myriad of useful functionalities that aid the survival of various flora and fauna. Imitating these biological surfaces, Prof. Cheung's team has developed various functional surfaces. For example, inspired by the water-repelling property of lotus leaves, the team has created micro-patterns on glass surfaces to prevent water and dirt from sticking. This makes them ideal for external mirrors and other hard-to-reach surfaces that benefit from self-cleaning properties. Additionally, butterfly wings appear colourful because nanostructures on them cause light waves to diffract and interfere. Similarly, Prof. Cheung's team has achieved colourful finishes on metals by mimicking such nanostructures.



07 POWER THAT BENDS

PolyVentures

POWER THAT BENDS

Foldable and rechargeable textile-based battery powers the next generation of wearable devices with exceptional durability, energy density and wearer comfort

When you imagine wearable technology, you may think of your fitness tracker bracelet that monitors your vital signs. But smart apparel and intelligent textiles are now smarter and more wearable than ever. For example, there are yoga pants that use haptic feedback to help you align your body into correct poses. Sports tops can heat up or cool down based on your body temperature. You can even send real hugs to your loved ones remotely using a t-shirt that simulates touch through haptic telecommunication technology.

Wear a wire

Intelligent textiles are fabrics and garments that can sense, process, upload and download data. They can monitor general health and medical conditions. They can also capture and store energy from sunlight and body heat, and use it to power other devices. They can even heat up, cool down, change colour and respond to their environment. Of course, as garments, these textiles must be comfortable, breathable and soft to the skin. With their advanced features and futuristic appeal, it comes as no surprise that sports junkies, health enthusiasts and even Instagram celebrities eagerly await the latest products. Experts predict that the market for wearable electronics will be worth over US$150 billion annually by 2026.

That being said, wearable electronics can only be as good as their batteries – the lighter and smaller a wearable device is, the harder it is to store enough energy for a decent running time. To complicate the issue further, batteries in intelligent textiles need to be flexible and washable. With these challenges in mind, Prof. Zijian ZHENG, Department of Applied Biology and Chemical Technology, led a research team to develop a high-performance textile-based rechargeable

Prof. Zijian ZHENG

Chair Professor of Soft Materials and Devices, Department of Applied Biology and Chemical Technology
Director, PolyU-Daya Bay Technology and Innovation Research Institute
Associate Director, Research Institute for Intelligent Wearable Systems
Associate Director, University Research Facility in Materials Characterization and Device Fabrication

Prof. Zheng received his Bachelor of Engineering degree in Chemical Engineering from Tsinghua University (2003) and his PhD in Chemistry from University of Cambridge, UK (2007). After a short period of postdoctoral training at Northwestern University, US, he joined PolyU in 2009 as Assistant Professor. His research focuses on developing soft materials and devices for wearable, skin-attachable, and implantable electronics. Prof. Zheng has published around 250 papers in high-impact journals such as *Science, Nature, Nature Materials, Nature Electronics, Advanced Materials*, etc. He has also filed more than 50 patents, and delivered more than 200 invited talks at international conferences.

Founder
EightOSix Technology Company Limited

EightOSix Technology

lithium-ion battery. Not only is their battery flexible, compact and high in energy density, it can also withstand all sorts of mechanical wear and tear without compromising performance and user safety. This makes it the perfect energy source for future wearable devices.

Worse for wear

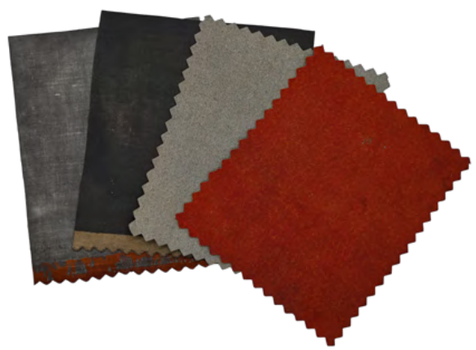
Most handheld electronics, such as smartphones and tablets, use conventional lithium-ion rechargeable batteries made with metal foil or metal plates. These batteries are rigid, bulky and heavy – not practical in intelligent textiles. Although bendable lithium batteries are available on the market, these are only slightly more flexible than conventional batteries, and not flexible enough for use in intelligent textiles. They also store little power. "Bendable batteries still work if they are curved, but – due to their rigid and brittle metal foils – not if they are folded," explains Prof. Zheng. "For a battery to truly function well on wearable devices such as heated jackets and smart insoles, it needs to have the same consistency and flexibility as fabric. That was how we came up with the idea of replacing the metal foil with a metallic fabric."

Capacity, durability and safety

To make the fabric conduct electricity, the team developed a patented award-winning Polymer-Assisted Metal Deposition (PAMD) technology. This technology involves grafting polymer brushes onto yarns and then depositing

highly conductive copper and nickel metal particles onto the polymer. The resulting metallic fabric is more conductive than metal foils and has a larger surface area for storing charge, resulting in excellent electrical performance. Despite a thickness of less than 0.5mm, a textile-based lithium-ion battery can store more than twice the amount of electricity as a bendable lithium battery of the same volume – a battery the size of a name card can store 200mAh of energy. This high conductivity also enables faster charging. After 500 charge-and-discharge cycles, the battery still retains 80% of its original energy capacity and can last for up to 1,000 cycles.

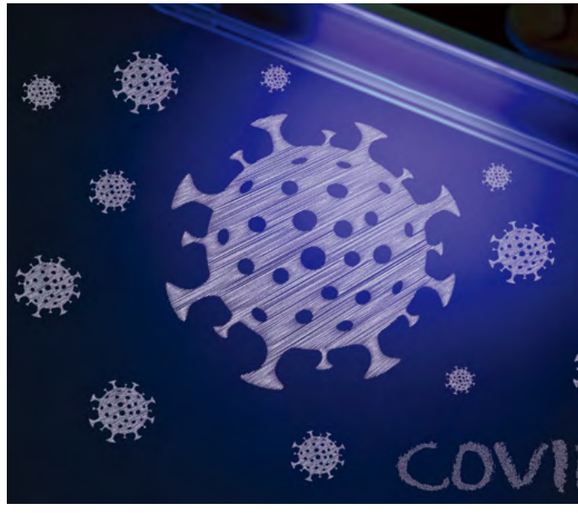
Ideal professional sports apparel should be able to tolerate the physical demands of various sports and resist normal wear and tear. The textile-based lithium-ion battery offers an extra competitive edge in this regard as it can withstand harsh mechanical impacts without breaking down or posing any safety hazards. In tests, the battery functioned normally after being repeatedly folded in half, twisted at different angles, and crumpled over 1,000 times. It was then



hammered, pierced by nails, and partially cut with scissors. Incredibly, it still worked as if nothing had happened, without overheating, catching fire or bursting. This means textile-based lithium-ion batteries are safe even in cases of traumatic accidents. What's more, clothing powered by a textile-based lithium-ion battery can be machine-washed just like regular gym clothes without removing the battery.

A start-up to power up life

To commercialise the textile-based lithium-ion battery, Prof. Zheng co-founded a start-up, EightOSix Technology Company Limited, which was accepted into the three-year Incu-Tech incubation programme at the Hong Kong Science and Technology Parks. In collaboration with an engineering consultancy, EightOSix developed an illuminated safety vest that caters to the specific needs of construction workers at night. Powered by a textile-based lithium-ion battery packing 460mAh of energy, the vest can light up for 9.5 hours on a single charge. It offers three lighting modes for different uses and weighs just 260g.



The COVID-19 pandemic has increased public awareness of hygiene practices. Many people have become more diligent in disinfecting high-touch surfaces and personal belongings. Germicidal ultraviolet light, better known as UVC, with wavelengths ranging from 180 to 280 nanometres, is one of the most popular methods for sanitising surfaces. With its short wavelength, UVC stops viruses and bacteria reproducing by mutating their DNA, thus preventing them from being copied correctly. This has led to the development of wardrobes with a built-in UVC lamp, handheld UVC wands, and even UVC eyewear cases.

However, high-powered UVC requires up to 1,500mAh of energy to run properly, and most conventional lithium-ion batteries are too heavy and bulky. For those who care about personal hygiene as much as their immaculate makeup, EightOSix has designed a UVC cosmetic bag powered by a textile-based lithium-ion battery. Thanks to the battery, the bag offers portability, softness and style while providing effective sanitation.

EightOSix is also exploring the integration of its textile-based lithium-ion batteries into thermal control garments, health-monitoring apparel, smart skin and smart shoes. The rechargeable battery's flexibility and energy density has opened a world of endless possibilities for designers and manufacturers of wearable electronics. With a power source that is foldable, machine-washable, and impact-safe, Prof. Zheng and his team are helping usher in the next generation of wearable devices beyond our wildest imagination, making our lives better, easier and healthier.

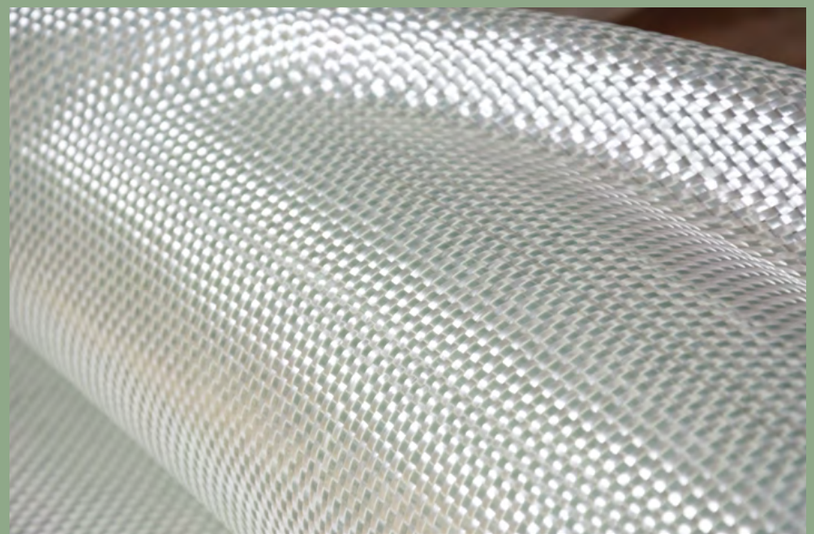
DIGGING DEEPER

Bendable vs foldable

Batteries, as we know them, are usually cylindrical. Like the batteries we put into a TV remote control, they are rigid and often bulky. This is because they need a hard, sturdy case to protect the brittle metal foils inside. But times have changed. Nowadays, rechargeable batteries can be as thin as 0.5mm, with the flexibility of a soft fabric that can be folded neatly and tucked into a drawer. To keep up with the expanding market in intelligent textiles, Prof. Zheng led a team to develop a textile-based lithium-ion battery. The team replaced the fragile metal foils found in traditional batteries with a conductive fabric that is both flexible and resilient. Cotton, PET and nylon fibres are coated with a polymer that bonds thin metal films to the fibres so well that the metal stays attached to the fibres even if the battery is distressed and warped. While other companies are also developing bendable batteries, Prof. Zheng's start-up, EightOSix, has pioneered to use a metal-coated fabric as the electrode material. Its battery is also the only truly foldable option available, with a bending radius of about 1mm.

Metallic glass-fibre fabrics (MGFs)

In wearable electronics, you have to wear a battery pack to power the electric circuit. Of course, no one wants to wear something heavy and bulky. That is why researchers are constantly looking for ways to reduce the weight of rechargeable batteries, enabling them to store more energy with less weight. This goal also applies to the textile-based lithium-ion battery developed by Prof. Zheng's team. Recently, the team has made its flexible battery lighter and more powerful by using conductive metallic glass-fibre fabrics (MGFs). In traditional batteries, a current collector connects the electrode to the external circuit. This current collector takes up much of the weight of a battery but does not itself store energy. The team thus came up with the idea of replacing typical copper or aluminium current collectors with MGFs that weigh up to 60% less. With their electrochemical stability, low sheet resistance, mechanical strength and fire resistance, MGFs are excellent choices for the flexible batteries of the future.



08 HITTING THE BULLSEYE

PolyVentures

HITTING THE BULLSEYE

Cutting-edge technologies improve cancer diagnosis and treatment with personalised care plans and precision approaches that target cancer cells accurately

Cancer is the leading cause of death worldwide. Every year, about 10 million people succumb to the disease, accounting for one in every six deaths globally. One of the most common treatment options is radiation therapy, which approximately 60% of cancer patients receive. Radiation therapy uses beams of intense radiation to kill cancer cells, but it may also damage healthy cells. The goal of modern radiation therapy is thus to deliver high doses of radiation to cancer cells as accurately as possible while avoiding damage to healthy cells.

"This is what we call precision radiotherapy," explains Prof. Jing CAI, Department of Health Technology and Informatics, who led a research team

Prof. Jing CAI
Associate Dean, Faculty of Health and Social Sciences
Professor, Department of Health Technology and Informatics

Prof. Cai is a Fellow of the American Association of Physicists in Medicine (AAPM). He earned his PhD in Engineering Physics in 2006 and then completed his clinical residency in Medical Physics in 2009 at the University of Virginia, US. He worked at Duke University, US, from 2009 to 2017 as Assistant Professor and then Associate Professor before joining PolyU in 2017. His research interests include medical imaging, radiation therapy, artificial intelligence, and bioinformatics. He serves on the editorial boards of several prestigious journals in relevant fields.

Technical Advisor
MedVision Limited

MedVision

Dr Alvin Chun-hang MA
Associate Professor, Department of Health Technology and Informatics

Dr Ma obtained his PhD from The University of Hong Kong (HKU) in 2009 and received further post-doctoral training at the Mayo Clinic, Minnesota, US. He returned to HKU in 2013 as Research Assistant Professor before joining PolyU in 2016 as Assistant Professor, and was later promoted to Associate Professor in 2022. His research focuses on the applications of the zebrafish model in translational medicine, from evaluation of disease-related genes to development of novel therapeutics. He is also a co-founder of ZeBlast, a biotechnology start-up supported by the incubation programme of the Hong Kong Science and Technology Parks Corporation.

Co-founder
ZeBlast Technology Limited

ZeBlast

to develop the use of AI in precision radiotherapy. "Precision radiotherapy has three main goals: to provide the right treatment, to target the right patients, and to apply radiation at the right time." Meanwhile, in the same department, Dr Alvin Chun-hang MA uses zebrafish as model organisms to determine the clinical features of acute myeloid leukaemia in humans. This is useful for targeted therapy and personalised medicine.

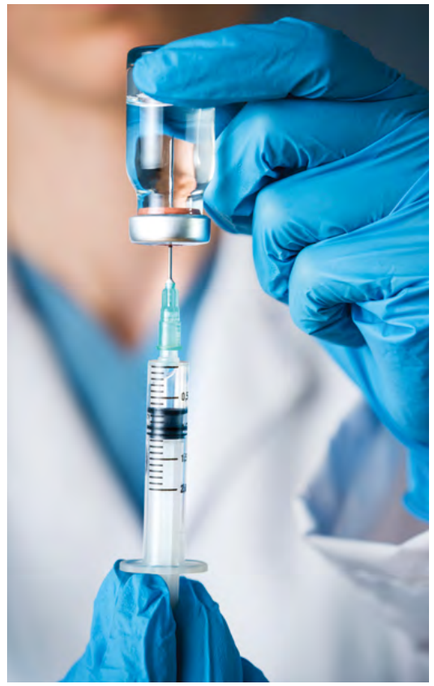
The right treatment

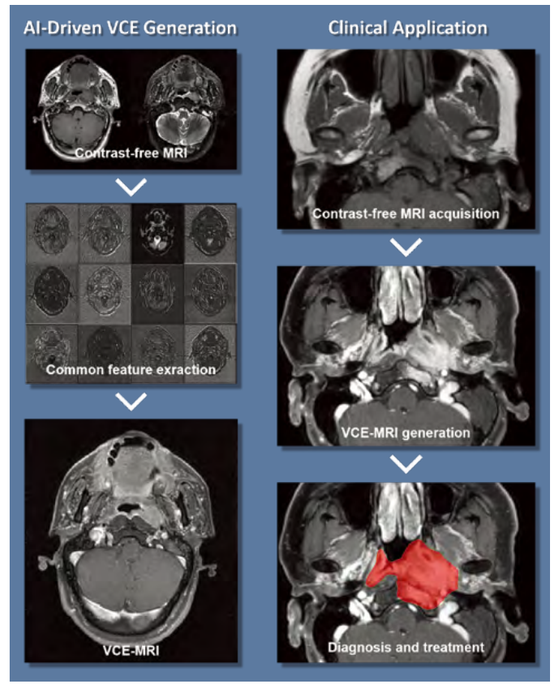
Precision radiotherapy aims to kill cancer cells while avoiding damage to healthy cells. But this is not as simple as it sounds. Accurately determining the volume and shape of a tumour is extremely

challenging. The radiation dose must be optimised to minimise its toxic effects, while patient well-being, as well as treatment response and outcome are all essential factors to consider. To address this challenge, Prof. Cai's team developed a strategy for radiation therapy targeting lung cancer patients while trying to avoid those parts of the lungs that are most important to the organ's function.

"We developed the world's first AI-based mapping method that synthesises lung perfusion images from CT images," says Prof. Cai. Perfusion is the flow of blood through a particular organ or tissue. The team's Functional Lung Avoidance Radiotherapy (FLART) is based on perfusion measurements derived from CT images of the lungs. These measurements show how much blood flows through different parts of the lungs, which is related to how well those parts are working. FLART then avoids directing radiation to highly functional regions, reducing lung injury and improving treatment outcomes. Compared with the existing practice of radiation therapy, FLART reduces the risk of radiation-induced lung injury by 5 to 8%.

To determine the volume and shape of a tumour, contrast agents that highlight tumorous tissues are sometimes used to enhance MRI images. However, these agents often contain gadolinium, a toxic substance. "Tumorous cells have different properties than surrounding normal cells. This information is embedded in regular MRI images," explains Prof. Cai. "Although such information may not be visible to the human eye, our AI-powered system has





learned to read these nuanced differences and virtually enhance the contrast of regular MRI images without using gadolinium." Prof. Cai's Virtual Contrast-enhanced MRI without gadolinium costs significantly less than using gadolinium-based MRI contrast agents, yet has an accuracy rate of 89%, which is comparable to gadolinium-enhanced images. To ensure that this new technology benefits those who need it, Prof. Cai's research team members co-founded MedVision Limited, a PolyU start-up nurtured in the PolyVentures ecosystem that aims to revolutionise cancer diagnosis and treatment, offering a safer and cost-effective alternative to contrast agents and empowering healthcare professionals to provide the best care possible.

Precision radiotherapy can also be administered in the form of brachytherapy. This technique involves implanting radioactive seeds in or near the cancer, and is commonly used to treat prostate cancer. However, the current clinical standard is to scan the prostate and its surrounding tissues with ultrasound, which can produce images that are blurry and unclear. This makes it hard to accurately identify the anatomical structure of the prostate. To address this, Prof. Cai uses AI to read ultrasound images for image segmentation – a technique to divide images into regions based on predefined categories. This approach has an accuracy rate of over 95%, saving time and relying less on the subjective judgement of radiologists. Using AI-powered segmentation for prostate cancer brachytherapy, radioactive seeds can be implanted more precisely in specific positions.

For the right patients

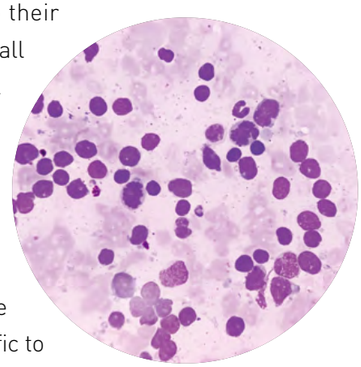
Precision medicine is the practice of tailoring treatment plans for each patient according to their demographics, genetics and clinical data, such as imaging results, blood chemistry and medical history. Prof. Cai's team uses AI and big data analytics to cross-match patient data with thousands of patient records to develop care plans that best suit each individual patient's needs.

At the right time

Another crucial factor in radiation therapy is time. As cancers may move when a patient breathes, still images may not be adequate to locate cancers in the thorax and abdomen. "Tumours may move 1 to 2cm during shallow breathing, and up to 5cm during deep breathing," explains Prof. Cai. Thus, to boost the accuracy of radiotherapy and reduce the toxic effects of radiation on healthy cells, Prof. Cai's team developed advanced 4D Magnetic Resonance Imaging (4D-MRI) and 4D Magnetic Resonance Fingerprinting (4D-MRF) techniques. A specific type of 4D-MRI, 4D-MRF not only measures tumour motion during breathing, but also accurately quantifies tissue properties such as density and the interaction between different tissues. Clinically, these techniques have been proven to target moving cancers, such as liver cancer, more precisely. This reduces the probability of radiation-induced liver damage from 50% to nearly 0%.

Zebrafish model for leukaemia treatment

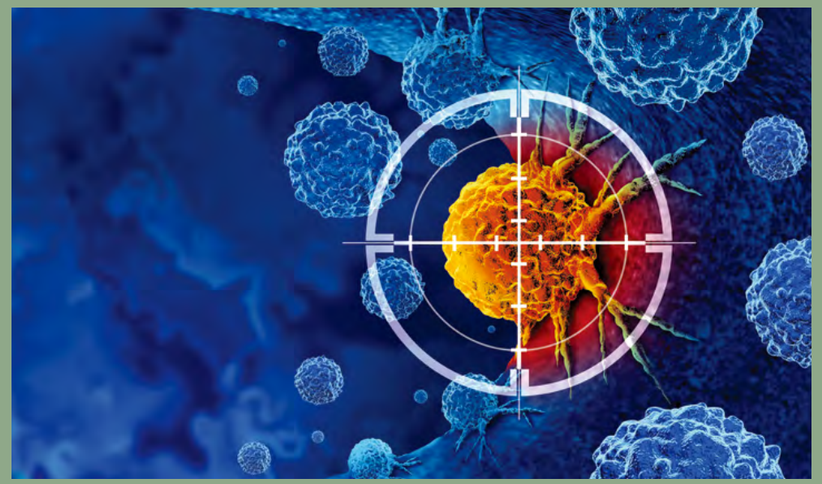
Drugs must be tested rigorously before they are approved for use on human patients. First, they must be tested in a laboratory setting, then on animals, and finally on human subjects. Zebrafish are often used as model organisms for scientific research due to their similar genetic makeup and biological pathways to humans. The small size of zebrafish, together with their high reproductive rate, chemical permeability and ease of observation, also make them preferred biomedical model organisms. This explains why Dr Ma's team uses zebrafish to examine the clinical features of acute myeloid leukaemia in humans. "Basically, we introduce over 30 different gene mutations in different combinations into the zebrafish to test how each combination contributes to the development of leukaemia and the specific response to the current treatment. We also try to find new target molecules specific to the physiology of leukaemia cells for targeted therapy," explains Dr Ma.



In his research, Dr Ma has also discovered that phenylthiourea, an inhibitor of melanin production, induces autophagy – a natural process in which cells clean out damaged or unnecessary components – in zebrafish embryos. This discovery has sparked academic interest in the potential role of autophagy in melanoma progression and inhibition. To harness the potential of his research for practical use, Dr Ma co-founded an academic-led start-up, ZeBlast Technology Limited, to provide clinically relevant, off-the-shelf, and validated zebrafish models to accelerate drug developments for blood, heart and brain diseases.

Prof. Cai's and Dr Ma's research outcomes have greatly increased accuracy in diagnosing and treating various cancers. Their work is helping healthcare professionals tailor the best care plans for patients, accompanied by improvements in prognosis and quality of life.

DIGGING DEEPER



Precision cancer treatment

Every person is different, and every cancer case is unique. Although cancer treatments have always been personalised to some extent, the latest trend is to tailor treatment plans according to the individual characteristics of each patient, such as their genes, risk factors, and proteins in their cancer cells. When a cell divides to make new cells, its genes should be copied exactly. However, sometimes genes may not be copied correctly. This is called a mutation. Not all mutations are harmful, but some are, and can lead to cancer. Having an abnormal gene may increase the risk of developing certain cancers. A specific gene change may also affect the prognosis of a cancer patient. In precision cancer treatment, a patient is tested for certain gene or protein changes. These changes, known as biomarkers, affect how cancer cells respond to certain treatments. In addition to analysing a patient's profile for a customised care plan, Prof. Cai's team also uses advanced technologies, including AI, deep learning, and big data analytics, to target cancer cells more accurately in radiation therapy. This minimises the side effects on healthy cells.

Molecular target

The most common treatments for cancer include surgery, radiation and chemotherapy. Targeted therapy has received much media attention due to its mild side effects and outstanding effectiveness when combined with other types of cancer treatments. Targeted therapy uses drugs or other chemicals to precisely identify and attack certain types of cancer cells. One way to do this is to target specific molecules that cancer cells need to survive and spread. These are called molecular targets. Cancer cells are constantly undergoing a series of chemical processes. By identifying the proteins or molecules that are uniquely used or needed by cancer cells, but not by healthy cells, cancer cells can be killed or their growth can be blocked by removing these specific molecules without affecting the healthy cells. Other pathways of targeted therapy include blocking chemical signals that cancer cells need to grow blood vessels, delivering cell-killing substances to cancer cells, and instructing the immune system to find and kill cancer cells. Dr Ma's team uses zebrafish as model organisms because they share similar chemical pathways and protein metabolisms with humans. By introducing cancer mutations into zebrafish, the team can model human cancer and determine the molecular signatures of cancer cells. This will lead to the identification of new molecular targets to detect and treat cancers.

09 MIND MATTERS

MIND MATTERS

AI-powered brain image analysis models and XR-based cognitive training greatly improve diagnosis and treatment of cognitive decline and dementia

Have you ever opened the fridge only to forget what you were looking for? Have you ever walked right past the dry cleaner, forgetting to pick up your jacket? We all become forgetful as we age. Yet dementia is not an inevitable part of ageing. Although there is currently no cure for Alzheimer's or Parkinson's disease, up to 40% of dementia cases can be prevented or delayed. The key is to detect dementia as early as possible so that intervention and treatment can be provided before symptoms progress. Unfortunately, there is no single conclusive test to diagnose dementia. Typically, diagnosis is based on a combination of cognitive tests, medical history review, blood tests and imaging assessments. These are often subjective and qualitative. To address this challenge, Prof. Harry Jing QIN and Prof. Thomas CHOI, School of Nursing, developed AI models that can accurately and precisely identify dementia using automated technology to analyse brain scans and other medical information.

In addition to early detection and treatment, research is also focused on improving the quality of life for people living with dementia. People with dementia often experience unexplained mood swings and may find it difficult to express

Prof. Harry Jing QIN
Professor, School of Nursing
Director, Centre for Smart Health, School of Nursing

Prof. Qin is a renowned expert in harnessing advanced technologies, particularly XR and AI, for various healthcare and medicine applications. He won the Hong Kong Medical and Health Device Industries Association Student Research Award for his PhD study on VR-based simulation systems for surgical training and planning, and won five best paper awards for his research on AI-driven medical image analysis and computer-assisted surgery. He served as a local organisation chair for MICCAI 2019, a technical programme committee member for dozens of academic conferences, an invited speaker at many talks, and a referee for most prestigious journals and conferences in relevant fields.

Prof. Justina Yat-wa LIU
Associate Head (Postgraduate Education) and Professor, School of Nursing

Prof. Liu is a leading nurse researcher focusing on using gerontechnology, such as virtual reality, wearable sensors, and m-health technologies, to implement exercise, nutritional and psycho-behavioural interventions for older adults with frailty. Her work addresses fatigue, sarcopenia, and low social participation. Ranked among the top 2% of cited scientists in her field in 2021 and 2022, Prof. Liu has successfully secured numerous grants and commercialised her research products, earning recognition with international awards like the Asia Gold Award in QS Reimagine Education 2022. She was also inducted into Sigma's 2024 International Nurse Researcher Hall of Fame.

Dr Daphne Sze-ki CHEUNG
Adjunct Associate Professor, School of Nursing

Dr Cheung is a gerontological nursing scientist with extensive clinical and research experience focusing on dementia care, related symptom management, and dementia carer support. Through interdisciplinary collaboration, she has pioneered a Music-with-Movement Intervention for people with cognitive impairment and their family carers. Her successful integration of technology into dementia care is recognised internationally and has received excellent testimonials from users. She is now working in Australia and ready to translate her research to address the global needs of dementia care.

their feelings. This may result in behavioural symptoms and even physical aggression. As extended reality (XR) technologies – including virtual reality (VR) and augmented reality (AR) – become more popular, research shows that such tools are a useful form of non-pharmacological therapy. XR tools can improve the quality of life and well-being of people living with dementia, especially their emotional health and social connectedness. Tapping into the promising potential of XR, Prof. Justina Yat-wa LIU and Dr Daphne Sze-ki CHEUNG, School of Nursing, spearheaded research on XR-based systems specifically designed for older people in Hong Kong. Their aim was to slow cognitive decline and alleviate the emotional and behavioural challenges faced by individuals living with dementia.

AI models for dementia screening

Early signs of dementia can be subtle, and early cases may slip under the radar. Recent research has demonstrated that neuroimaging techniques can identify biomarkers that indicate early signs of dementia. High-resolution brain images carry a wealth of details about brain structure and function, but such details are often too subtle for the human eye to spot. To cope with this, Prof. Qin and Prof. Choi developed 3D convolutional neural networks to automatically detect cerebral microbleeds (CMBs) in brain images. CMBs are important biomarkers of cognitive decline. "Studies show that subjects with Alzheimer's disease often have more CMBs in their brains than healthy

individuals. In terms of location, lobar haemorrhages – bleeding in the lobes of the brain – are more relevant to Alzheimer's disease than CMBs in other areas of the brain. Cognitive impairments and dementia are also linked to the density and location of CMBs," explains Prof. Qin. "Further studies are needed to confirm the exact relationships between CMBs and dementia. Our advanced deep learning networks can provide valuable data and insights that will help researchers conduct further investigations."

Another issue with brain imaging involves efficiency. A typical brain 3D MRI scan involves hundreds of slices. Traditionally, radiologists have had to examine each of these slices manually. This process is time-consuming, tedious, and difficult to perform on a large scale. What's more, to interpret the images accurately, radiologists need a sophisticated knowledge of brain anatomy. To overcome this limitation, the professors developed a new deep learning architecture – a novel voxelwise residual network (VoxResNet) to automatically segment key brain tissues in 3D images. This is of great significance for diagnosing a wide range of neurodegenerative diseases.

AI models that combine multiple types of data improve the accuracy of dementia screening by identifying crucial genetic variations known as single nucleotide polymorphisms (SNPs) and brain regions related to the development of the disease. These models can automatically assess dementia risk with an average accuracy of up to 88%.

XR-based dementia interventions

Besides early screening and diagnosis, people living with dementia also benefit from advancements in technology. Prof. Liu and her team developed the region's first immersive VR simultaneous dual-task (motor-cognitive) game-based training system to enhance the cognitive and physical health of older individuals with mild cognitive impairment. Research shows that cognitive training is more effective when performed simultaneously with physical exercises. "In the past, cognitive training was boring – subjects were asked to sit still and name a colour or a shape. We decided to incorporate unique contexts with a local flavour so that our clients would find it relevant to their lives and memories," explains Prof Liu. The tasks are based on storylines that patients are familiar with, such as remembering the route number of a bus, getting on and off a bus, shopping for groceries in a supermarket, and cooking a meal at home, while simultaneously working their leg muscles on a pedal exerciser. "Most clients are astonished by what they see in the VR headset, and they enjoy it a lot. Since we launched the programme in 2020, it has the lowest drop-out rate of all cognitive interventions. Most participants also showed significant improvement on their Montreal Cognitive Assessment Test score after the training." The team has already signed an agreement with a commercial partner to promote and sell the system in markets that cater specifically to older adults. More information is available on YouTube at www.youtube.com/watch?v=ATle6sIVLxQ&t=2s.

Another way to enhance cognitive functioning among people living with dementia is through therapeutic music intervention. However, these therapies are usually conducted in hospitals, clinics and treatment centres by certified music therapists. As a result, the number of patients who can benefit from music therapy is limited. To enable patients to benefit from music intervention in the comfort of their own home, as well as in community centres, Dr Cheung led a research team to develop an AR-based therapeutic music-with-movement game app. The app, which runs on an Android tablet, includes four games: users are asked to move their bodies to music that they are familiar with, play a motion-sensing musical instrument following a rhythm, listen to the lyrics of their favourite old songs, and join a reminiscence-based group discussion provoked by a certain song. Players see their faces on the tablet screen with animated effects, cartoon characters, and hints about body movements, creating an engaging and entertaining experience. Results showed that participants' cognitive and psycho-social well-being improved after 12 sessions of music-with-movement treatment. Their caregivers also reported that participants appeared happier, and were more willing to open up to others after several sessions. The caregivers themselves also experienced lower stress levels.

Technologies promise a better future, and people living with dementia can also benefit from the outcomes of research and development. Researchers in the School of Nursing have made an outstanding contribution to the understanding of dementia, greatly advancing its diagnosis, treatment, and clinical practice, while improving the well-being and quality of life of those living with dementia.

DIGGING DEEPER

Three stages of dementia

Alzheimer's disease has three stages: (1) preclinical, (2) mild cognitive impairment (MCI), and (3) Alzheimer's dementia. In the preclinical stage, symptoms are not noticeable to the patients themselves or those around them. However, new brain imaging technologies can reveal amyloid plaques and neurofibrillary tangles – biomarkers signalling the development of Alzheimer's disease. When these biomarkers are detected, timely monitoring and early treatment may help delay the onset of Stage 2. In Stage 2, patients often recognise a mild decline in their memory and thinking abilities. They may need more time to make simple decisions. They may forget about a recent conversation or event. However, not all individuals with MCI have Alzheimer's disease. With cognitive training and brain exercises, an individual with MCI can improve their memory and thinking abilities. Alzheimer's disease is often diagnosed in Stage 3, when symptoms progress to interfere with patients' daily lives. They may forget what they have bought and buy the same thing over and over again. They may become overly suspicious, accusing others of stealing their money. They may neglect their personal hygiene. When this happens, it's time to seek professional help.

Therapeutic music intervention

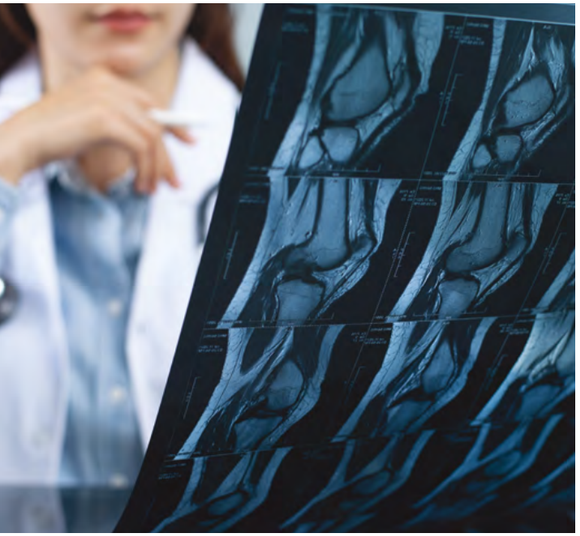
People with diminished cognitive function experience difficulties in managing stress. These difficulties manifest as changes in individuals' behavioural and emotional states. Music is a non-verbal medium of communication and can especially benefit older adults struggling with verbal expression. For such individuals, music can help alleviate stress and distract from stressors. In fact, music intervention involving listening, singing or dancing to music is a helpful way to alleviate the behavioural and emotional symptoms of individuals living with dementia. A recent systematic review revealed that music intervention can de-escalate symptoms of agitation. There are various types of music intervention, but an active approach using music-with-movement techniques is notable for its ability to engage participants and yield positive effects. To promote therapeutic music intervention for the benefit of older adults with dementia, Dr Cheung led a team to modify conventional music-with-movement intervention using a novel AR-based system. This system has proven an effective way to alleviate the emotional and behavioural symptoms experienced by individuals living with dementia.

10 JOINT EFFORT

PolyVentures

JOINT EFFORT

AI-powered models enable early screening, self-management, exercise therapy and prognosis prediction of knee osteoarthritis, greatly improving quality of life among patients



Knee osteoarthritis is a degenerative joint disease affecting over 500 million people worldwide that can severely limit mobility and quality of life, especially in older adults. This debilitating condition, often caused by wear and tear, can lead to chronic pain, depression, and an increased risk of cardiovascular disease, stroke and dementia. While early diagnosis and treatment can slow progression, conventional diagnosis of knee osteoarthritis relies on expensive and bulky gait analysis systems that are only available in hospitals or laboratories, making

community-wide screening impossible. It's time to rethink this costly and time-consuming approach to diagnosing and treating this major obstacle to active ageing.

To enable early screening and intervention of knee osteoarthritis, Dr Chunyi WEN, Associate Professor, Department of Biomedical Engineering, led a research team to harness the power of AI and augmented reality (AR) for patient care in community service settings and public hospitals. This innovative multi-faceted prognosis prediction system can achieve an accuracy rate of up to 90% and is expected to save up to HK$1.4 billion of medical expenses a year in Hong Kong.

AI-powered video-based motion analysis for early screening of knee osteoarthritis

Using a deep learning algorithm, Dr Wen's team devised a marker-free motion analysis platform that detects the early symptoms of knee osteoarthritis from videos shot with smartphones. "We ask subjects to shoot video footage of themselves standing up from a seated position, as well as walking at a normal pace. Preferably, they shoot the videos from two angles, one from the side and one from the front, in five repeated cycles," explains Dr Wen. The algorithm then automatically locates the joints, and measures the angles, angular velocities, and accelerations

Dr Chunyi WEN

Associate Professor, Department of Biomedical Engineering

Dr Wen, a former registered medical doctor in Mainland China, has redirected his passion towards musculoskeletal ageing and regeneration research, driven by a vision to transform elderly patient care. Collaborating with a multidisciplinary team of local experts, including orthopaedic surgeons, therapists, nurses, and biomedical engineers, he is dedicated to revolutionising the clinical landscape by leveraging artificial intelligence. Dr Wen is a member of the Board of Directors of the Osteoarthritis Research Society International (OARSI) and an Associate Editor of *Osteoarthritis and Cartilage*, the official journal of OARSI.

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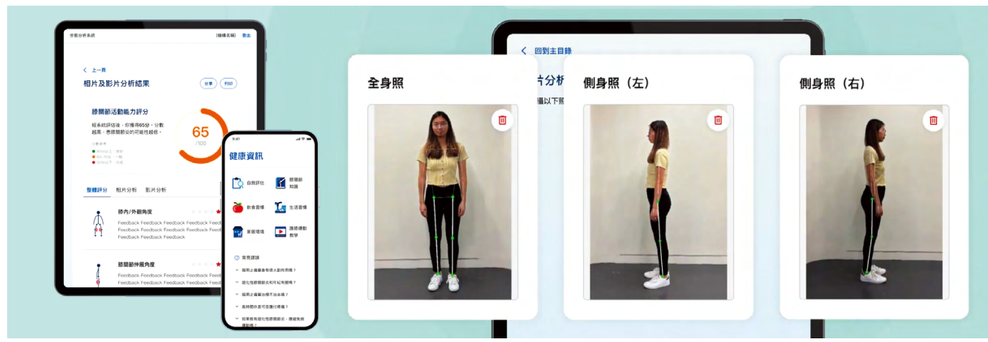
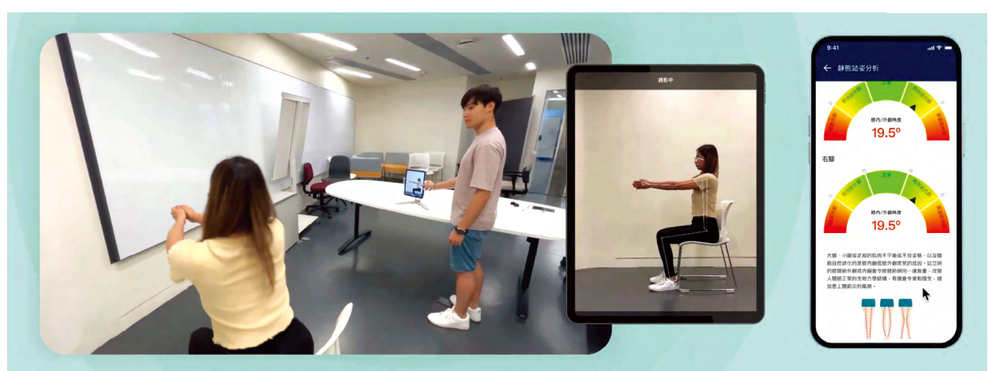
of the joints as a subject stands up from a chair or walks. Rather than simply counting, as in a sit-to-stand test, the system provides a thorough, objective and quantitative measurement of afflicted knee joint motion and its link with adjacent ankle and hip joints. It offers a solid foundation for clinicians whose work involves surgical and rehabilitation planning. As the system does not require state-of-the-art equipment and healthcare professionals for measurements and analysis, it is much more affordable. This makes it a viable solution for screening knee osteoarthritis patients in the community.

AR-enabled motion tracking for self-managing knee osteoarthritis

To enable individuals to assess their risk of developing knee osteoarthritis, and to enable existing patients self-manage their symptoms, the team has developed a free smartphone app. The app includes a risk assessment that uses AI to analyse a user's demographics, medical history and lifestyle, and calculates how each factor contributes to the risk of developing knee osteoarthritis. App users can also upload sit-to-stand and walking motion videos, which the app uses to analyse the user's gait. Based on the survey and gait analysis, the app shows the user's risk of knee osteoarthritis progression and recommends ways to slow the progression.





The app also offers health tips, lifestyle tips, and exercise tutorials. Although damage to knee joints cannot be reversed, patients can manage their symptoms through lifestyle changes such as losing weight and exercising regularly to strengthen their leg muscles. "That's why the app comes with an AR feature to guide users through training at home, showing them the correct posture, measuring their range of motion, and tracking their progress," says Dr Wen. The app is especially useful for remote communities without access to physiotherapy clinics, and for patients to manage their symptoms between physiotherapy appointments.

Multi-faceted knee osteoarthritis risk prediction and prognosis system

Current clinical practice lacks an effective triage process for individuals suffering from knee osteoarthritis. Given Hong Kong's rapidly ageing population, knee osteoarthritis is increasingly common, while public healthcare professionals often fail to address patients' needs promptly. To address this shortcoming, Dr Wen's team uses a combination of big data analytics and AI to assess a patient's risk of requiring knee replacement surgery in the future. This assessment takes into account a range of clinical data, including a patient's demographics, self-reported

lifestyle habits, medical history, and radiographic images extracted using sophisticated image analysis techniques. Together with the video-based knee osteoarthritis screening model, this system can predict patients' likelihood of requiring surgical knee replacement in the next eight years with an accuracy rate of 93%.

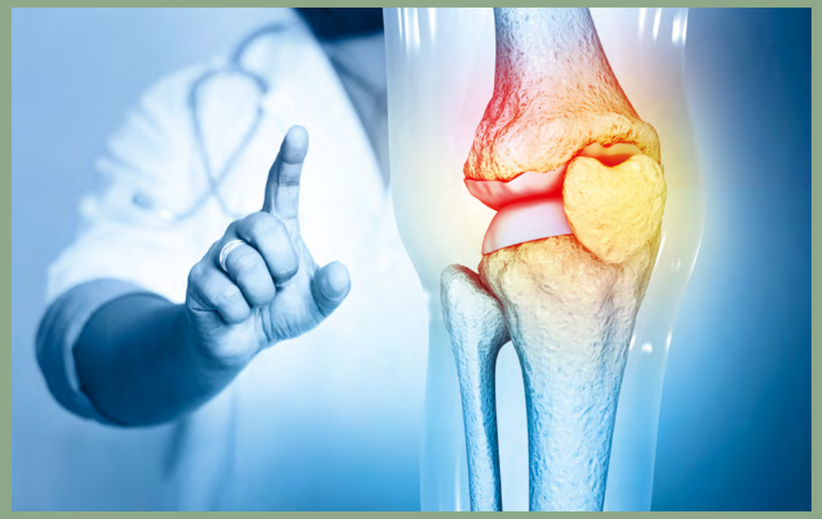
"We built the first model using data from over 20,000 subjects in the US," explains Dr Wen. "Then we collaborated with the Hospital Authority, who granted us access to over 5,000 data sets of anonymous local patients. We've also been conducting clinical trials in Hong Kong. So far, we've recruited over 800 local patients. We're confident that our AI-powered model will become even more accurate as the database grows, with more local cases." At the time of writing, a private hospital in Hong Kong has approached the team, hoping to adopt the knee osteoarthritis risk and prognosis prediction system for its patients.

Start-up with a social mission

To commercialise its AI-enabled models, Dr Wen's research team has founded a start-up, CLAIRE Clinical AI Research Limited, with Dr Wen as an honourable company consultant. Through this PolyU start-up, he empowers his students to translate research into practice, tackling the pressing issue of knee osteoarthritis. With funding from PolyU and the HKSAR government, CLAIRE developed both Android and iOS versions of the smartphone app for self-management of knee osteoarthritis. To teach target users to navigate the app, the team has hosted many workshops and recruited PolyU undergraduate volunteers to organise workshops in the community. CLAIRE has also introduced its video-based knee osteoarthritis screening platform at the Hong Kong Housing Society Elderly Resources Centre, as well as four other community centres, reaching over 1,000 older people.

Using cutting-edge technologies and advanced algorithms, Dr Wen has helped knee osteoarthritis patients receive early diagnosis and treatment. This has the potential to improve the quality of life of millions and save valuable healthcare resources in Hong Kong and the Greater Bay Area, resonating with PolyU's motto – "To learn and to apply, for the benefit of mankind".

DIGGING DEEPER



Early detection and intervention

If we find a water leak in our home, we locate the source and patch it before our whole home floods. If we have a credit card balance that keeps rolling month after month, we seek help from a financial advisor to consolidate our debt. The same applies to our health – it makes sense to nip a minor ailment in the bud before it can become a major threat to our well-being. In the context of knee osteoarthritis, early diagnosis is important as it opens a window for early intervention that can positively alter the course of the disease and greatly improve long-term outcomes. Knee osteoarthritis occurs when the cartilage cushioning the ends of the bones wears down over time. Such damage to the joints cannot be reversed. The earlier the disease is diagnosed, the sooner the progressive loss of articular cartilage can be slowed. Dr Wen's suite of AI-powered models helps diagnose knee osteoarthritis early so that patients can begin exercises and make lifestyle changes before their symptoms worsen.

Stand up!

Inspired by the 1980s Cantonese smash hit 'Stand Up' sung by late pop singer Leslie Cheung, Dr Wen's team came up with a slogan to encourage the public to abandon a sedentary lifestyle to improve their knee health. They launched a campaign called 'Stand Up', urging older people to sign up for early screening for knee osteoarthritis and start living an active life. Throughout the campaign, participants were enthusiastic about the team's AI-powered platforms, which added fun to otherwise boring check-ups and exercises.

"Participants were happy to have the videos shot, and to interact with our workers. They also found our AR workout app amusing. When they enjoy using the app, they're more likely to stick to the training that it recommends," says Dr Wen.

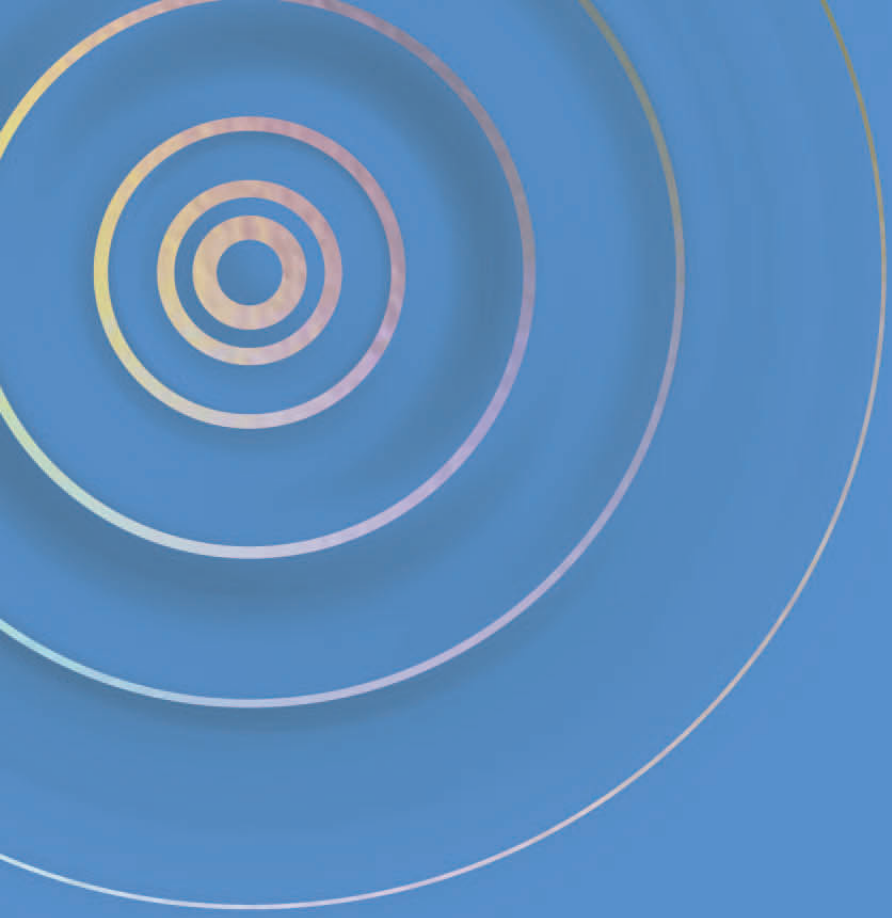
POLYIMPACT AND POLYVENTURES EXPLAINED

Hong Kong Polytechnic University (PolyU) aspires to be an innovative world-class university with a strong sense of social responsibility, driven by its motto, "To learn and to apply, for the benefit of mankind". We take pride in harnessing our excellence in education, research and knowledge transfer to drive **PolyImpact** – inventions and innovations by the PolyU community that create long-lasting and real-world impact.

We do this by nurturing future-ready talents and entrepreneurs, and empowering visionary academics and researchers to uncover knowledge and transform research excellence into impactful innovations that address pressing global challenges. We cultivate next-generation entrepreneurs through **PolyVentures**, our signature start-up ecosystem, to develop novel ideas and cutting-edge solutions in driving positive change in society. The comprehensive support in our ecosystem encompasses every stage of the entrepreneurial journey – from education and ideation to incubation, acceleration, and fundraising.

By propelling **PolyImpact**, we open up new frontiers in deep space exploration, improve health and wellbeing, boost economic growth and foster sustainability for the betterment of Hong Kong, the Nation, and the world.

PolyImpact PolyVentures



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