RESEARCH
@HKUST

2017

The Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong

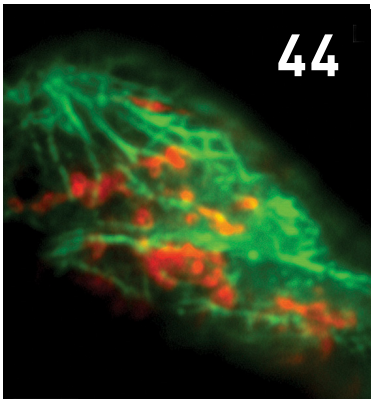
CONTENTS

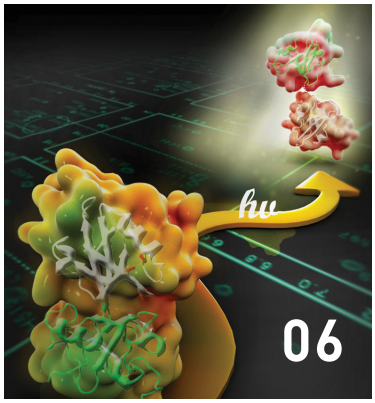
香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

RESEARCH @HKUST

RESEARCH@HKUST
is published by the Office of the Vice-President for Research and Graduate Studies.

(852) 2358 5984
research@ust.hk
www.ust.hk/research





A Word from the Vice-President for Research and Graduate Studies

Welcome to the second issue of *Research@HKUST*.

HKUST celebrated its 25th Anniversary last year, marking another milestone in the University's short but remarkable history as a leading education and research institution. As an early member of the University, I find it particularly gratifying to have had the opportunity to grow and to build the University alongside first-class colleagues. It is an equally fulfilling experience to watch the University thrive on the world stage today.

With a total of nearly 650 faculty and 5,000 postgraduates, HKUST is numerically small in institutional research terms. Thus, our international punch and strategic partnerships with other elite global universities have little to do with size. Rather, the University's reach and reputation are founded on vision, commitment, prescience and collaborative endeavor that nurture and advance a spirit of curiosity, discovery, and innovation.

The University comprises the Schools of Science, Engineering, Business and Management, Humanities and Social Science, and an Interdisciplinary Programs Office, which are supported by a network of research institutes and centers, and central research facilities. Establishing expertise over a wide range of fields ensures that HKUST is well-positioned to engage in both education and research across disciplinary boundaries. At the same time, the purpose-built main Academic Building, housing a range of different departments in one location, fosters a varied but close-knit community of top minds. This unique collegiate atmosphere serves as an intellectual springboard for novel ideas and initiatives, and encourages cross-disciplinary collaboration among faculty and students to tackle the grand research challenges of our times.

In this issue of *Research@HKUST*, we are pleased to share with you a selection of the exciting and diverse research endeavors that are ongoing at the University. These range from curiosity-driven breakthroughs to applied development and knowledge transfer, including projects aligned with the University's five areas of strategic focus – data science, autonomous systems and robotics, sustainability, design thinking and entrepreneurship, and public policy – and other high-impact undertakings.

We highlight our structural biology explorations into the intricate mechanisms of our cells and DNA; research into geomaterials and environmental water engineering to safeguard and sustain the world's rapidly growing cities; breakthroughs in data science and human-robot interaction; and elucidation of the realm of China's finance. We continue to shine light on young faculty trailblazers. There is also a new section on technological advances leading to spinoff companies.

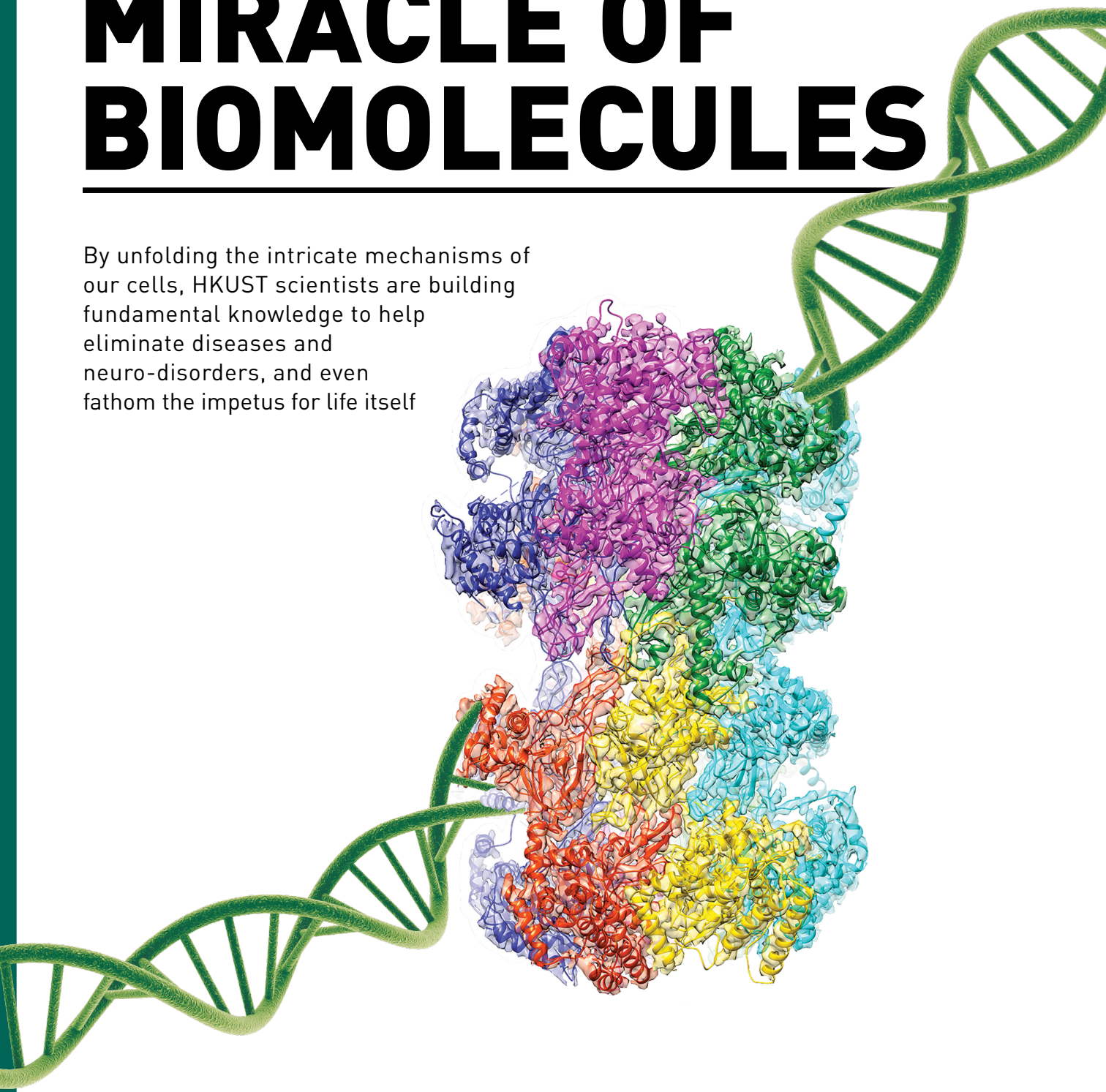
Indeed, we live in challenging and fast-moving times. As researchers and global citizens, we will continue to extend the frontiers of knowledge across disciplines and put our collective minds together to address global challenges. As this edition highlights, we are relentless in our efforts to achieve excellence through research and knowledge transfer with significant impact to society.

“We will continue to extend the frontiers of knowledge across disciplines and put our collective minds together to address global challenges”

PROF NANCY IP
Vice-President for
Research and Graduate Studies

THE MIRACLE OF BIOMOLECULES

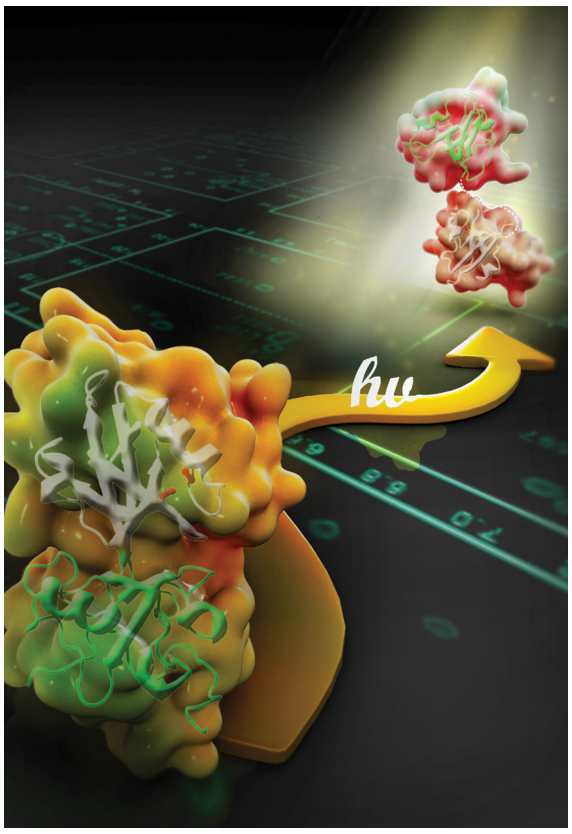
By unfolding the intricate mechanisms of our cells, HKUST scientists are building fundamental knowledge to help eliminate diseases and neuro-disorders, and even fathom the impetus for life itself



Basic research is like searching for a dark object of unknown shape in a dark room. Something is there. We do not know what it looks like. Only when you find it, can you say "Ahh, this is it!"

With 30 trillion cells in operation at any given time in a typical human adult – practically a universe of its own – how can we ever understand ourselves? Yet our bodies' smallest and most intricate mechanisms are now on the brink of being fathomed as structural biology, with the aid of super-powerful imaging technologies, shines unprecedented light on the miniscule and miraculous molecular world continuously at work within.

Structural biology sets out to reveal what biomolecules, such as proteins, enzymes and nucleic acids, look like at atomic-scale resolution, how they acquire their structures, and how alterations in these structures affect their functions. Daunting as the challenge may seem, curiosity and the quest for new knowledge are driving forward the University's cell biologists,



geneticists, biophysicists, and computational chemists in pursuit of greater understanding of our molecular make-up.

Utilizing X-ray crystallography, cryo-electron microscopy (cryo-EM), nuclear magnetic resonance (NMR) spectroscopy, super-resolution microscopy, and high-performance computing, HKUST scientists are delivering world-leading fundamental breakthroughs in areas related to the human brain and neuronal structural biology, DNA replication machinery, replication initiation, and the transcription process.

New phenomena observed and accounted for may lead to target therapeutics for neurological disorders such as depression, autism, and schizophrenia, explanations and treatments for cancers, and insights into questions such as why we age and how to prevent it.

BRAIN POWER

The infinitely complex human brain has recently given up more of its secrets. The Zhang Lab, a global leader in neuronal structural biology, has discovered the answer to a question that has been puzzling neuroscience for 60 years. Led by Prof Mingjie Zhang, the team has also shown that this finding has significant potential for greater understanding of neuropsychiatric disorders such as autism and schizophrenia, which afflict millions around the world.

The question involves one of the Zhang Lab's areas of focus over the past two decades: transmission of neuronal signals in synapses. In the human brain, the 1.5-liter powerhouse that determines everything about us, information is transmitted through around 10^{11} neurons. They send or receive signals from other cells, and from one neuron to the next, through synapses, which number around 10^{15}. Given the large numbers and nanometer scale of the molecular machinery, tracing the atomic-level underpinnings of this network is a daunting challenge.

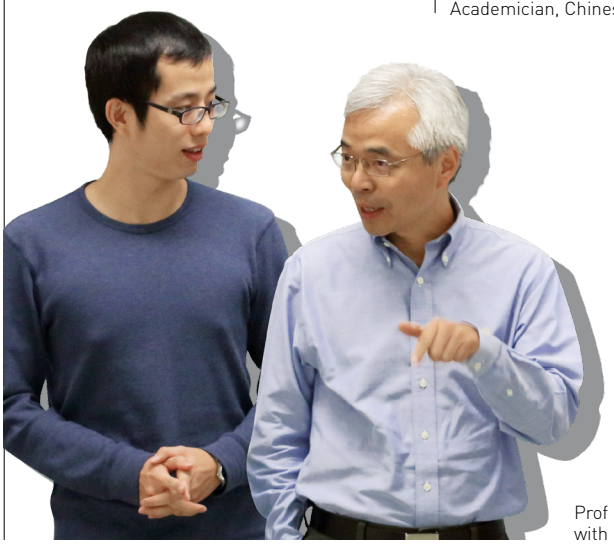
But specializing in synapses, a fundamental unit for all kinds of neurons, has provided the Zhang Lab with a valuable way of cutting through such complexity. Synapses function as signal receiving, processing and transmitting apparatuses as well as memory storage and retrieval sites. Derived from the Greek word meaning conjunction, they encompass a jumping-off point for the signal, called the presynaptic terminal, a fluid-filled space or cleft, and the landing area or postsynaptic density.

While the postsynaptic density and its role as the signal receiving and processing unit was first observed six decades ago, how it forms and organizes itself remained a mystery. It is this enigma that the Zhang Lab has successfully solved.

A focus on two abundant proteins in the postsynaptic density, SynGAP and PSD-95, led to the discovery. These proteins were already of interest to scientists as they were known to play a major role in learning and memory; and if mutated, were implicated in disorders such as autism and epilepsy. However, the breakthrough was accomplished by building on the Zhang Lab's years of leading studies on synaptic signaling complex assembly and regulation; and its systematic work to comprehend how the proteins critical for receiving and interpreting diverse brain signals are coordinated to form synaptic functional networks.

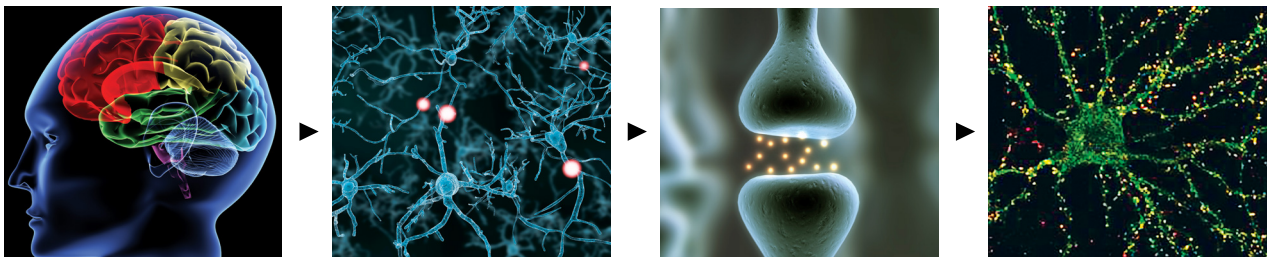
> "I chose to focus on the synapse, a tiny compartment just 0.5 micron or less in diameter, because it is a basic unit of communication for all kinds of neurons. The principles we learn from our studies will be applicable to essentially every aspect of brain cells"

PROF MINGJIE ZHANG
Kerry Holdings Professor of Science,
Academician, Chinese Academy of Sciences



Prof Mingjie Zhang (right) with Dr Menglong Zeng.

Transmission of neuronal signals in synapse



Network ▶ Circuit ▶ Synapse ▶ Neuron

Led by Prof Zhang, team leader Dr Menglong Zeng (then a PhD student and now a postdoctoral fellow) and other researchers leveraged such experience – and hundreds of lab hours spent in sample preparation to obtain the high-quality specimens necessary for rigorous characterization – to elucidate the structural basis for the interaction between SynGAP and PSD-95.

The study showed the two protein molecules could form an autonomously assembled network structure, with SynGAP forming a coiled-coil trimer that can bind to multiple copies of PSD-95. The researchers then deduced and demonstrated that binding of the two proteins induces the spontaneous formation of stable "oil-like" droplets through phase transition, a fundamental physical chemistry phenomenon.

Excitingly, additional findings indicated that the SynGAP/PSD-95 protein complex is crucial for SynGAP stabilization in the postsynaptic density and for stopping neurons from overstimulation, or hyper-excitation. Experiments involving mutated SynGAP proteins, as found in autistic patients' brains, showed that such proteins altered the "oil-like" droplet formation, causing the synapse to overreact. This mechanism could explain why the genetic disorder occurs.

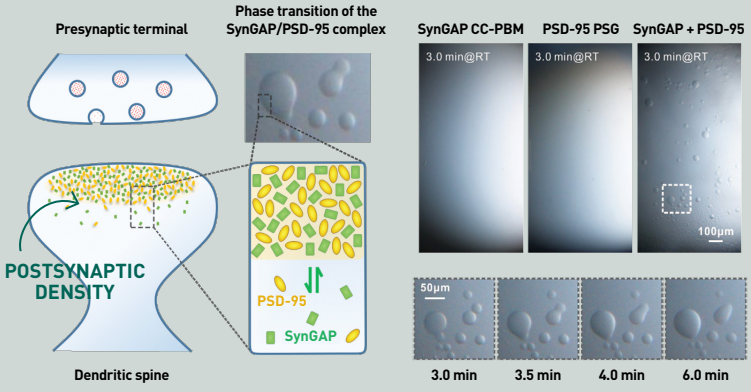
The project was carried out in collaboration with a research group from Johns Hopkins University and published in *Cell* in 2016.

"The identification of phase transition as the underlying mechanism for synaptic protein assembly formation could lead to a paradigm shift in thinking in the biology field overall, as it represents a principle beyond those located in traditional textbooks," Prof Zhang said. "Phase transition can explain why in a test tube you can have the same protein existing in two phases, one extremely dense, the other diluted, and they can exchange. This is what we observed in living cells and systems but we didn't know how it happened. It may even be how the evolution of life got underway."

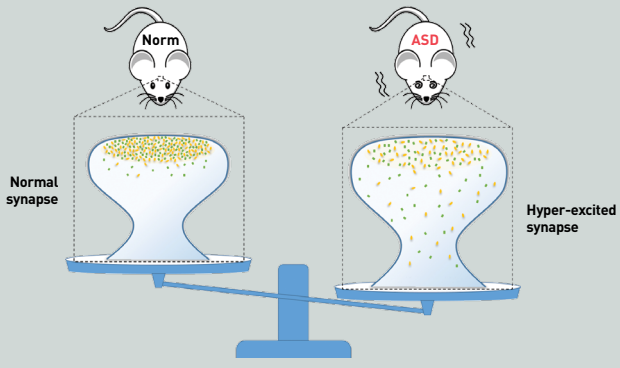
Over the years, research work by the Zhang Lab has been awarded numerous competitive grants, including the 2013 Areas of Excellence funding from the Hong Kong Research Grants Council, and led to a large number of publications in leading journals, including *Cell*, *Science*, *Developmental Cell*, and *Proceedings of the National Academy of Sciences* (*PNAS*).

The Zhang Lab is currently hard at work to explore whether other synapses, such as neuron-muscle connections, use phase transition to build synaptic protein assemblies. They are also hoping that the findings may offer new strategies for developing therapeutics for treating neuropsychiatric disorders such as autism, which currently have no effective treatments. "When and whether we are able to translate our findings into real drugs lie a long way forward from our discoveries. The important thing is we now have a new direction," Prof Zhang said.

Neurons communicate with each other via synapses.



Prof Zhang suggested a model for phase transition-mediated formation of the postsynaptic density (PSD). The phase transition occurs and "oil-like" droplets form when PSD-95 and SynGAP bind together. The finding answers an important neuroscience question of how PSD can form and stably exist.



The mice with mutations of SynGAP have hyper-excited synapses and show autistic symptoms.

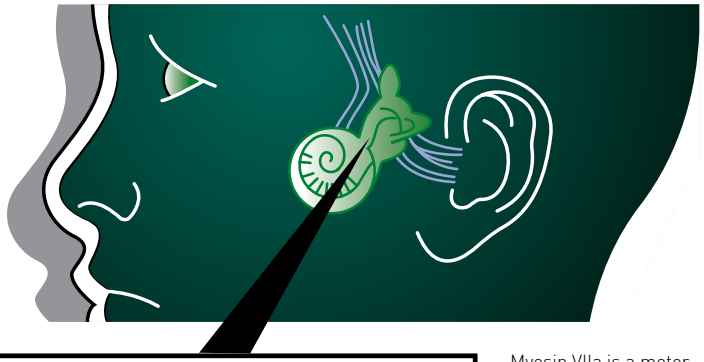
Deciphering Proteins

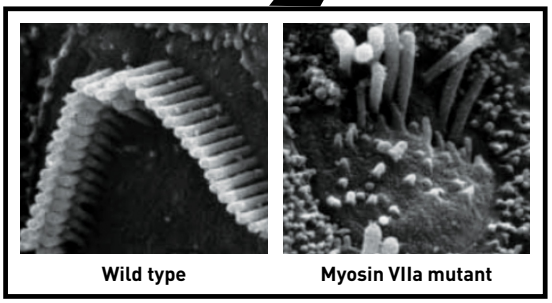
The mysteries of the vastly complex world of proteins are being unraveled through many different structural biology advances at the Zhang Lab. The following highlights several key discoveries:

Hereditary Deafness and Blindness

Researchers have systematically elucidated proteins (for example, myosin I, myosin III, myosin VI, myosin VII, myosin X, and myosin XV) and protein interaction networks (for example, the Usher complex) that are required for the proper development and function of sound-detecting hair cells in human ears and light-receiving photoreceptors in human eyes. This work led to significant findings that mutation of myosin VIIa can affect the proper development and normal functioning of hair cells in human ears and eyes which can lead to severe deaf-and-blindness (Usher syndrome) in new-borns and young children. (*Cell*, 2009; *Science*, 2011; *Nature Structural and Molecular Biology*, 2015; *eLife*, 2016; among others)

Using fruit fly photoreceptors as a model, Prof Zhang and his team found that the INAD scaffold protein in microvilli of photoreceptors in animal eyes can undergo a light-dependent architectural or molecular shape change, regulating light signal detection speed and signal output amplitude, as a result of a rapid oxidation/reduction cycle. The finding expanded understanding of how animal photoreceptors can detect such a broad intensity of light signals at a very rapid speed and how human eyes in the same way regulate their response to different light conditions; and helped research into disorders such as night blindness and retinitis pigmentosa. (*Cell*, 2011)

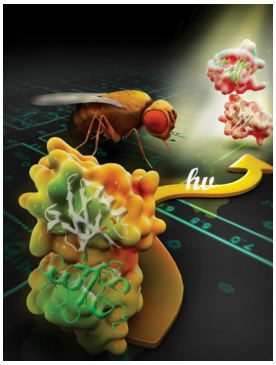




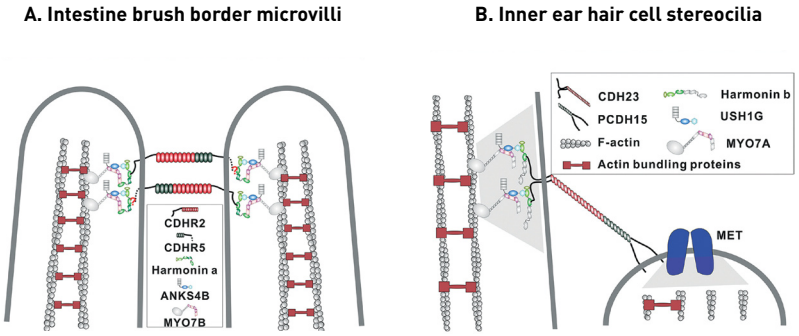
Myosin VIIa is a motor protein responsible for transporting various cargos in living cells and maintaining stereocilia structures in hair cells. Genetic mutations in the cargo-binding tail of myosin VIIa, in complex with adaptor protein Sans, can cause Usher syndrome, a genetic disorder resulting in hearing and vision loss or impairment.

Digestive Aid

The Zhang Lab has assisted in the identification of gene mutations that may cause digestive diseases. The team recognized the striking similarities, both in appearance and mechanistic features, between two structures in separate parts of the human body that perform vastly different functions. Stereocilia are organelles of hair cells that respond to fluid motion for different functions in the human body, including hearing and balance. Brush border microvilli, located on the surface of epithelial cells in areas such as the small intestines and proximal tubules of kidneys, are cellular membrane protrusions that increase cells' surface area and help with absorption, secretion, and cellular adhesion. Findings showed that both systems use very similar sets of proteins to organize their multi-protein complex, building tip-links that can sustain mechanical strains. Current knowledge of stereocilia tip-link complex is more advanced than that of microvilli tip-link complex, thus by identifying the similarity between these two systems, existing understanding of the former may provide insight into understanding of the latter. They anticipate that this characterization will assist understanding of certain gut or kidney diseases. (*Developmental Cell*, 2016; and *PNAS*, 2017)



Research into the mechanisms underlying the light-detecting capabilities of fruit flies (drosophila) led to insights on human visual disorders.



Protein interaction networks in brush border microvilli (Figure A) and inner ear stereocilia (Figure B). Prof Zhang's studies characterized interactions biochemically and structurally in microvilli and discovered that microvilli and stereocilia tip-link complexes are strikingly similar.

INSIDE THE WORLD OF DNA REPLICATION

Unraveling Replication

When DNA replication goes wrong, the consequences can be catastrophic: an aborted fetus during the early stages of development, deformed organs during late-stage development, or cancer are just some examples. The challenge for scientists such as geneticist Prof Bik-Kwoon Yeung Tye and life scientist Dr Yuanliang Zhai is to understand the fundamental mechanisms at work in DNA replication in normal cells in order to identify and correct problems in diseased cells and stop the disaster from happening.

The intricate replication process, which only happens once in each cell cycle, has proved highly difficult to unravel, hampered by limitations on what scientists could see of the molecular machinery at work at the atomic scale. But research by the Tye/Zhai team, utilizing the latest cryo-EM technology in collaboration with Prof Ning Gao at Peking University, has recently led to pioneering advances that bring the previously unreachable into the realms of the achievable.

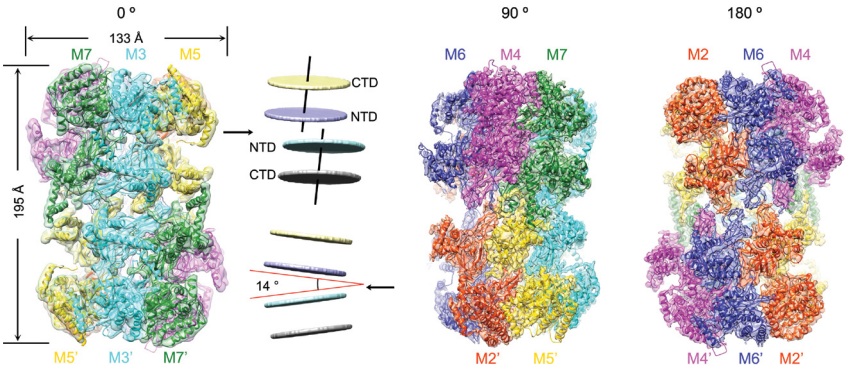
Due to the higher resolution now available from state-of-the-art cryo-EM technology, the scientists were finally able to solve one part of the puzzle: the structure of the core of the MCM2-7 helicase enzyme at the near-atomic level of 3.8Å. In accomplishing this significant endeavor, it became the first sub-nanometer structure reported for the MCM2-7 complex. The complex had been identified previously as having a major role in destabilizing and separating the double-stranded DNA during replication. But it had defied crystallization efforts so it had not been viewed through the established structural biology imaging technique of X-ray diffraction.

The findings were published and the impact analyzed in *Nature* in 2015. Some of the major advances in the article showed that: the two rings of a MCM2-7 complex form a tilted and twisted dimer through the N-terminal domain; and the central channel thus formed has four constriction points that immobilize duplex DNA for deformation.

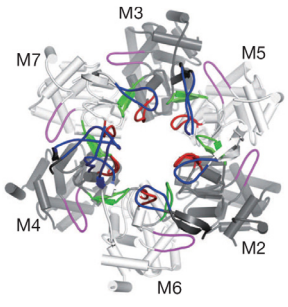
It was also a moving moment for Prof Tye, who in 1983 had published the first paper to name and identify the MCM2-7 complex as important in DNA replication in eukaryotes, following her research on yeast as an assistant professor at Cornell University. "It couldn't have been more gratifying, as I was literally and figuratively seeing the fruits of the hard work of an entire community that started from my own lab," she said.

Eukaryotes are organisms with a complex cell that has its genetic material stored within a membrane-bound nucleus. They include fungi, plants, and animals. Cellular mechanisms in eukaryotes are evolutionarily conserved and therefore similar in many ways, enabling researchers to learn about human diseases by studying yeast.

A major problem in preparing samples of complex molecular machines for studies is in keeping together the large number of components that make up these machines through multiple steps of purification. Another is the problem of scale. Dr Zhai, a HKUST PhD graduate and currently a research assistant professor, took up the



The tilted and twisted arrangement of two MCM single hexamers, the core of the replication licensing complex, at the resolution of 3.8Å.



Each subunit of MCM2-7 forms constriction points to immobilize DNA for deformation.

challenge. Rather than going through a labor-intensive process of purifying individual components and assembling them in a test tube, through finesse and perseverance he managed to purify pre-assembled MCM2-7 double hexamers from within yeast cells in a sufficient amount and quality for cryo-EM imaging.

Prof Tye's second discovery was published in *Nature Structural and Molecular Biology* in 2017. The team found that the single hexamer precursor of the MCM double hexamer in yeast formed a coiled structure – rather than the current suggested model of a closed-ring structure – giving new insights into double hexamer formation and indicating a spring-action mechanism may be involved in origin melting and the unwinding of the DNA. The single hexamer also forms the core of the helicase that unwinds DNA by encircling and traveling on one of the two strands. The fact that the core of this unwinding machine is a coil/spring suggests that the driving force that separates the two strands may be the repeated action of the spring.

The leading work is drawing scientific attention globally to the possibilities that await with the cryo-EM resolution revolution, as it has been labeled. "You could see the excitement when I reported the atomic model for the MCM complex at a meeting for the first time," Prof Tye said. "Clearly, researchers in the field feel that we can now move forward. If we can solve one part, then we can solve more parts, and by putting them together, we will see the whole DNA replication machine."

Prof Bik-Kwoon Yeung Tye (left) with Dr Yuanliang Zhai.

> "When you can't see clearly, you can only speculate. Now we can finally see the structure, we know what information to build on"
>
> **PROF BIK-KWOON YEUNG TYE**
> Visiting Professor of Life Science

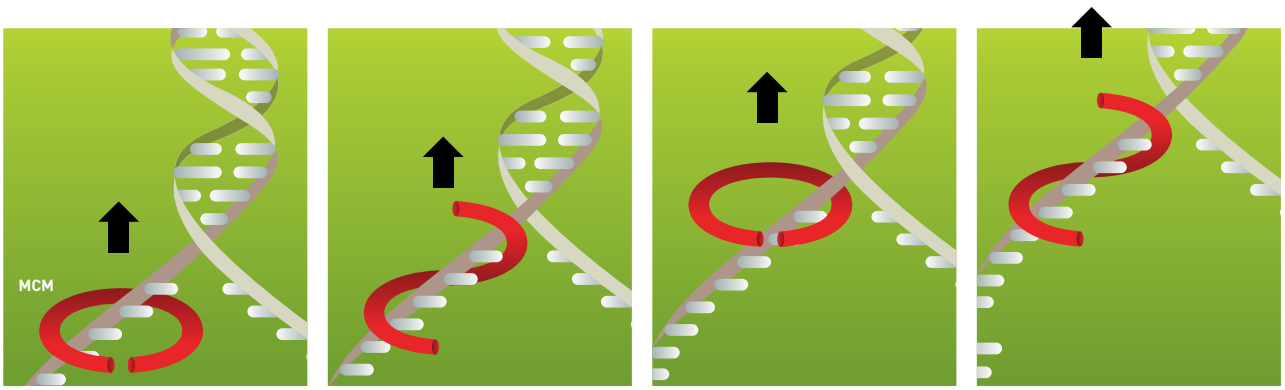
The Tye/Zhai group is continuing to view the MCM complex at different stages of the DNA replication cycle, combining what is seen through cryo-EM imaging with genetics and biochemistry to build atomic models and continuously add to fundamental knowledge. Prof Tye is also working with other HKUST colleagues, including NMR specialist Prof Guang Zhu, Prof Xuhui Huang on molecular dynamic simulations, and with mathematicians who can help in writing algorithms for image reconstructions.

Human DNA and the Origins of Life

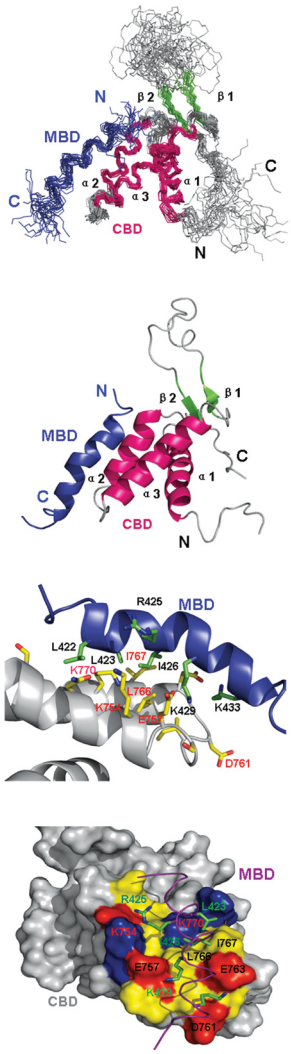
"I don't know about aliens. But here on Earth, bacteria, archaea, all kinds of life, as far as we know, involve DNA replication," noted Prof Guang Zhu. "It is one of the most fundamental biological processes. How can Nature achieve such outstanding precision time after time in such a complex process? I want to know the detailed molecular mechanism involving human DNA replication, the malfunctions that can cause cancer and other diseases, and to work toward strategies for the potential treatment of these diseases."

Prof Zhu's lab focuses on the challenging task of creating the human proteins he studies and the regulation of cell proliferation and differentiation, when a cell moves from non-specialized to a specific type of cell, such as a lung cell or a liver cell; and the application of new knowledge to assist drug development.

Breakthroughs in revealing structures and mechanisms in human DNA replication proteins include determining



Prof Tye's finding suggests a spring-action model for the MCM during the initial origin melting and the subsequent DNA unwinding (shown in figure).



NMR structure of Cdt1/Mcm6 complex solved by Prof Zhu provides insight into how mutations can disrupt the Cdt1-Mcm6 interaction and lead to impaired DNA replication. This provides a possible target for designing anti-cancer drugs.

the structure of the Cdt1/Mcm6 complex through NMR spectroscopy. The team was the first to reveal the details at atomic resolution of how the complex binds and how mutations can disrupt this interaction, impairing DNA replication (*Journal of Biological Chemistry*, 2010; *Nucleic Acids Research*, 2012), and providing a possible target for designing anti-cancer drugs. His collaborators on such work included Prof Chun Liang, Division of Life Science, who is interested in regulation of DNA replication both in normal cells and in relation to cancer; and Prof Bik Tye, who uses cryo-EM structures to map out the important interaction regions for Prof Zhu to delineate detailed structure-functions through NMR spectroscopy.

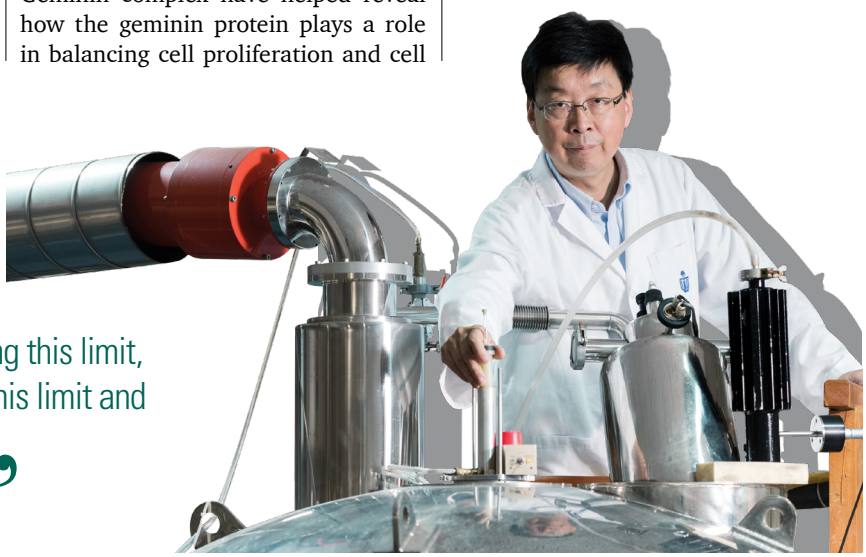
Prof Zhu's researchers also discovered the role of histone methyltransferase SET8 (*Cell Cycle*, 2008) and thus a new regulator suppressing DNA replication in the human cell cycle. The team is currently studying the Epstein-Barr virus (EBV), which recruits human DNA replication machinery for its own DNA replication and can play a part in nasopharyngeal carcinoma, a cancer of special relevance to southern China. In studying the interaction of EBV protein EBNA1 and human proteins, Prof Zhu is seeking to understand the binding mechanism used by the virus to explore the possibility of designing drugs to block virus replication in human cells and thus the disease.

In addition, his group's studies of the structure-functions of the Hox/Geminin complex have helped reveal how the geminin protein plays a role in balancing cell proliferation and cell differentiation (*PNAS*, 2012). The work has potential for novel therapeutic agents related to leukemia.

As an international front-runner in NMR methodologies, Prof Zhu has steered the University's Biological NMR Center since arriving at HKUST in the mid-1990s, advancing and leveraging the institution's world-class 500, 750 and 800 MHz NMR spectrometers to study, design, and develop experiments to reveal novel aspects of the molecular cosmos.

His leading work on NMR methodologies, for example the transverse relaxation-optimized spectroscopy (TROSY)-based methods, for the study of large biomolecules in solution was published in an array of papers from 1998 to 2002 in journals such as *Angewandte Chemie International Edition in English, Journal of Biomolecular NMR,* and *Journal of Magnetic Resonance* as well as included in textbooks. The biomolecular community now routinely uses some of these techniques. The work also gave HKUST an early global edge in NMR-based structural biology discovery.

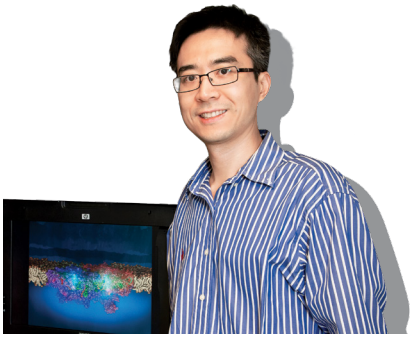
Work is ongoing in developing the next-generation of NMR technology. One avenue is to shorten NMR experimental time for studying fast biomolecular systems with new super-resolution algorithms. Prof Zhu is excited about its potential but not ready to reveal just yet how it may reshape the structural biology landscape!



"The Hayflick limit showed a normal human cell can divide around 60 times. But by searching and understanding the molecular mechanisms setting this limit, could there be a way to extend this limit and hence, prolong a human life?"

PROF GUANG ZHU
Professor of Life Science

DYNAMIC VISION



Proteins are the cell's workforce. They carry out an array of functions, often determined by their shape. However, proteins are dynamic and constantly moving, which current experimental imaging techniques find difficult to detect. Now cutting-edge research by Prof Xuhui Huang is realizing novel insights by leveraging computer simulations to "add dynamics, make a movie, and help elucidate what a protein does".

One of Prof Huang's main focuses is the multi-step transcription process whereby DNA information is used to create messenger RNA (mRNA), which after further steps is translated into the protein molecule encoded in the original gene. The transcription process is vital to the cell given that errors at this stage are implicated in relation to many diseases, including Alzheimer's, and in aging.

A major contribution to date has been to look at the dynamics of the backtracking step of transcriptional enzyme RNA polymerase II. This step self-corrects errors if something goes wrong to ensure that each messenger RNA matches the template DNA. "However, the process happens at a millisecond timescale (10^{-3}), and to create a millisecond computer simulation would previously have required a 1,000 CPU core from a super-computing center running non-stop for 150 years," Prof Huang said. He and his team bridged this time-scale gap through a new theory and algorithm development, based on the Markov State Model in combination with other statistical mechanical theories, bringing the time required down to months.

The advance allowed the team to collect data and images to examine the backtracking process. From this, they identified a residue, amino acid Rpb1 Threonine 831, which serves as a sensing probe to detect interaction difficulties between RNA that is not incorporated correctly and the template DNA, among other findings.

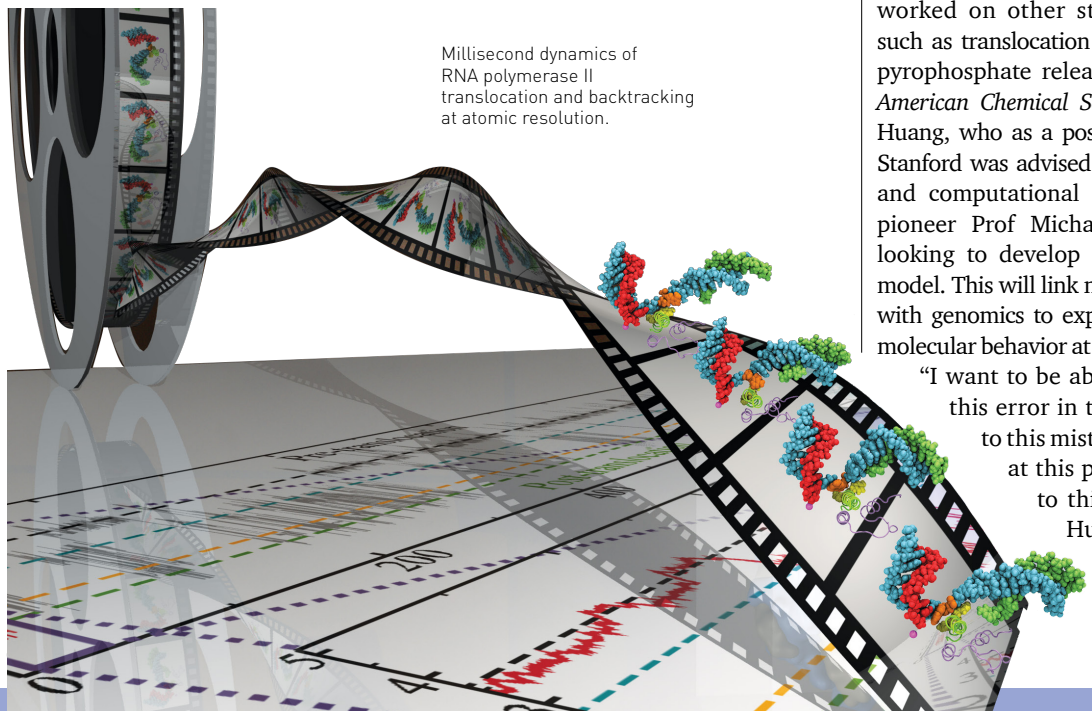
The team implemented the project and carried out data analysis in collaboration with a computer scientist at King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, where the super computing took place. "Extensive simulation comprising 25 billion molecular dynamics (MD) steps, initiated from crystal structures, modeled a biological process occurring at hundreds of microseconds, creating a massive dataset," Prof Huang said.

> "A lot of biologists have started to think that structural dynamics – a 'computer telescope' – is an important complement to existing structural biology. You can look at images as a function of time and tell how proteins operate"
>
> **PROF XUHUI HUANG**
> Padma Harilela Associate Professor of Science

A team member at the University of San Diego further validated the results. The research appeared in *Nature Communications* in 2016.

The Huang Research Group has worked on other steps in the cycle, such as translocation (*PNAS*, 2014) and pyrophosphate release (*Journal of the American Chemical Society*, 2012). Prof Huang, who as a postdoctoral fellow at Stanford was advised by Nobel Laureate and computational structural biology pioneer Prof Michael Levitt, is also looking to develop a kinetic network model. This will link molecular dynamics with genomics to explore the impact of molecular behavior at the system level.

"I want to be able to tell you that this error in the genome is due to this mistake of the enzyme at this particular step due to this mutation," Prof Huang said.

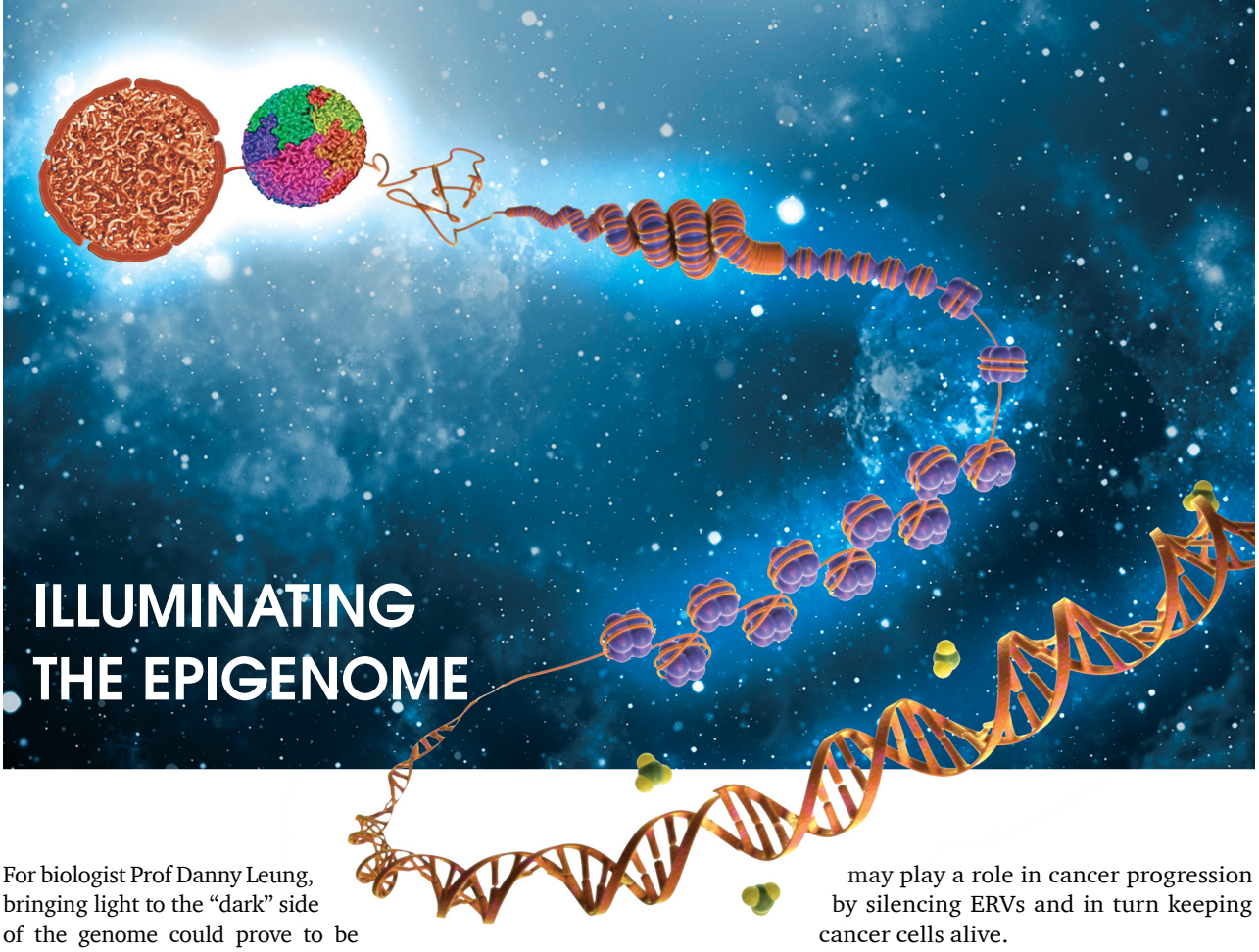


Millisecond dynamics of RNA polymerase II translocation and backtracking at atomic resolution.

Clockwise from top left:
Prof Danny Leung,
Prof Yi Wang,
Prof Angela Wu,
Prof Yonghoon Lee.

NEXT-GENERATION TRAILBLAZERS

Four young faculty with the vision to transform our understanding of the world



ILLUMINATING THE EPIGENOME

For biologist Prof Danny Leung, bringing light to the "dark" side of the genome could prove to be a key factor in finding out what goes wrong in cells to cause cancer and other human diseases. "All our building blocks are coded in our genes, yet this only represents 2% of the genome, which means 98% is non-coding. These parts have very important functions in normal biological processes but our knowledge of how they are controlled is limited. I like to call it the dark matter of the genome!"

Prof Leung's focus is on greater understanding of the epigenome, the layer on top of DNA that decides which pieces of DNA get activated or repressed, how epigenetic modifications of non-coding DNA are utilized in cancers and whether they facilitate cancer cells to stay alive. In particular, he seeks to elucidate the role of endogenous retroviruses (ERVs) in modulating gene transcription and the epigenetic mechanisms that silence these potentially harmful sequences. Such viruses make up 8% of the human genome, a significant amount. They have become part of our genome through evolution and have the capacity to affect how our genes are controlled.

Prof Leung has been working in this cutting-edge area of life science since his PhD at the University of British Columbia. Prior to joining HKUST in 2015, he had managed a branch of the US National Institutes of Health Roadmap Epigenomics Project. Recently, he received a 2017 Croucher Innovation Award, granted to a select group of rising star scientists from universities in Hong Kong to support their research over five years.

One major finding has shown that repressed harmful DNA sequences were reactivated by depleting the SETDB1 enzyme, resulting in the death of mouse embryonic stem cells. These mouse cells share commonalities with human cancer cells, such as melanoma, the most malignant type of skin cancer and one that is on the rise. The discovery suggests that SETDB1 may play a role in cancer progression by silencing ERVs and in turn keeping cancer cells alive.

Following confirmation of the function of SETDB1 in melanoma through experiments, including analyses of ERVs, Prof Leung's research will use the high-throughput and efficient system he has devised to screen for potential drugs that inhibit this protein. The findings will also provide insight into other cancers.

This type of epigenomic research has only recently become feasible due to the advancement in DNA sequencing technologies. Specialized equipment, for example the DNA sequencers that Prof Leung needs to carry out his work, is available in-house at the University's Biosciences Central Research Facility, helping HKUST life scientists to stay at the leading edge.

> "The 'dark' matter of the genome has been largely ignored until recently. Long thought to be junk, it is now clear that it isn't"

PROF DANNY LEUNG
Assistant Professor
of Life Science

In addition, Prof Leung is heading the Hong Kong Epigenomics Project, which draws together 15 groups from five institutions across the city, and has been elected a member of the International Human Epigenome Consortium. Data generated will be made publicly available allowing researchers around the world to use it.

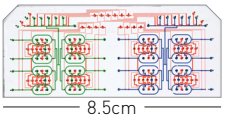
Prof Leung has published in *Nature, Proceedings of the National Academy of Sciences* (*PNAS*), and *Cell Stem Cell,* among others.

MAPPING OURSELVES

Imagine an interactive map of the human body, where you can simply click on a certain cell and see what type of cell it is and what it is doing, just like we can with Google maps. Despite our bodies being composed of trillions of complex cell types, such a map may not be too far in the future, thanks to innovation by bioengineers such as Prof Angela Wu.

The early career academic is helping to drive forward single-cell genomics, a recently emerging field that is enabling vision and understanding of what we are made of at an unprecedented resolution and complexity. Traditional methods study millions of cells; but Prof Wu and her team are unique even among one-cell researchers. While most study DNA and RNA separately, the Wu lab is seeking to extract both simultaneously to develop a more complete set of information about a cell.

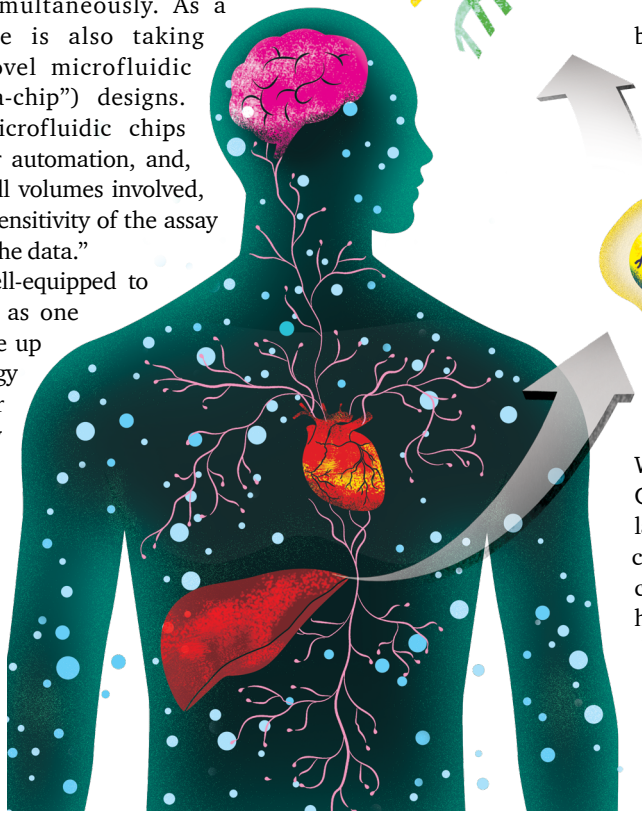
Microfluidic chip



Prof Wu, who has been selected as one of MIT Technology Review's 2017 "10 Innovators Under 35" in Asia, is working on a strategy for tagging DNA and RNA so they can be sequenced simultaneously. As a technologist, she is also taking advantage of novel microfluidic device ("lab-on-a-chip") designs. "I like using microfluidic chips because they offer automation, and, with the very small volumes involved, help improve the sensitivity of the assay and the quality of the data."

She is also well-equipped to handle such data as one of the first to come up with the methodology and framework for analyzing very complex single-cell datasets, when working as a postdoctoral fellow in Prof Stephen Quake's group at Stanford University.

Her contribution as a life scientist is her use of these single-cell tools to learn more about the origins of disease, for example, the fundamental reason – "big bang event" – that initiates a cancer. There are two current theories: the first is that a stem cell goes rogue and gives rise to a tumor, which can be discerned by looking at RNA; the second is that cancer results from the accumulation of a lifetime of mutations in the genome, discerned at the DNA level. "Through our technique profiling both DNA and RNA in an individual cell, we can see how the two explanations fit together. Such knowledge will really help us arrive at an overall unifying view of cancer initiation."



While Prof Wu works on colon and liver cancer, the findings are likely to be applicable to many tissue types.

The techniques being developed by Prof Wu are also highly relevant to the Human Cell Atlas project. This global initiative was launched in Fall 2016 by an international community of leading scientists to create a comprehensive reference map of different human cell types and their networks to better understand our health and how and why things go wrong. With that will come insight not only for scientists but for us all.

Prof Wu's research has been published in *Nature, Nature Methods, PLoS Genetics* and *Lab on a Chip,* among others.

> "Just as different people play different roles in society, different cells also have different functions in an organ. We can better harness different cell types for medicine if we study and understand them at the single cell level"
>
> **PROF ANGELA WU**
> Assistant Professor of Life Science, Chemical and Biological Engineering

TRACING THE INITIAL MOMENT OF THE UNIVERSE

It is one of the greatest unsolved mysteries for humanity: what the beginning of our universe looked like. Now research by Prof Yi Wang, an expert in cosmic perturbation theory, and his international collaborators, have unveiled a new prediction that provides fellow cosmologists globally with the most robust tool yet to plot what happened in the primordial moment of the cosmos.

Cosmic inflation is the leading paradigm of the primordial universe, in which the universe expanded exponentially. However, alternative scenarios with slowly expanding, slowly contracting, or fast contracting universes may also explain what cosmologists have observed. The problem is that the current way of observing the relics of the primordial universe is like stacking all the frames of a movie together. It is unknown which frame is earlier or later, or the speed that the "movie" is playing.

> "If I dare only to do the research where I am sure there is some outcome, I cannot do the research where there could be a great outcome"
>
> **PROF YI WANG**
> Assistant Professor of Physics

Working together with long-time collaborator Dr Xingang Chen, of the Harvard-Smithsonian Center for Astrophysics, and Dr Mohammad Hossein Namjoo, now at the Massachusetts Institute of Technology, the team identified a model-independent way of sequencing what happened in that initial moment, by using quantum fluctuations of heavy particles as a "clock". This clock marks the time of each frame of the "movie". Thus, it becomes possible to put the frames in the right order and "play" it at the right speed, to find out what happened at the primordial moment of our universe. Their 2016 paper, "Quantum Primordial Standard Clocks", published in the *Journal of Cosmology and Astroparticle Physics*, attracted global scientific and popular attention.

"Quantum mechanics implies that every object has an internal frequency as a clock. We applied this simple principle to the particles in the primordial universe," Prof Wang explained.

Prof Wang, a Stephen Hawking Advanced Fellow at the University of Cambridge before joining HKUST, looks forward to the moment that experimental physicists can use the clock to confirm empirically the evolution of the primordial universe. This will help in addressing the ultimate question: where we come from.

How does such research relate to society? "Science and technology are how modern society differs from ancient times. Fundamental science is of particular importance because it is the root of technology," he said. It is also essential that this curiosity-driven excitement and motivation to explore frontier knowledge is transmitted to the next generation. "Even primary students can be inspired by the origin of the universe," he noted.

Prof Wang's research findings have appeared in *Journal of Cosmology and Astroparticle Physics* and *Journal of High Energy Physics,* among others.

HOW TO SURVIVE AND SUCCEED IN K-POP

How can Korean pop music (K-pop) provide insights into career transitions? Prof Yonghoon Lee has made it the novel focus of empirical research as to how networks help or hinder career progress.

Prof Lee's work is timely, not only because of the recent global craze for K-pop, but the parallels he notes between careers in the creative industries and the gig economy in which freelancing is an increasingly common mode of employment. Without the security of traditional hierarchies to protect their employment, freelancers, including artists, must rely more heavily on their networks to prove their value and win a strong position in their industry.

Prof Lee has been tracking the career history of K-pop songwriters and the patterns in their collaborations, using a mixed methods approach of interviews and network analysis, first motivated by observing the struggles of his Korean songwriter friends. His research contribution draws on network theory to unpack some paradoxes in career survival and success.

From his study of K-pop songwriters, he found that a "closed" network of collaborators may be vital for survival in the early stages. While those with closed networks remain comfortable, those with an "open" network, joining people who are otherwise disconnected, may aim to hit the charts.

> "I want to uncover how creative people can manage their networks throughout their career"

PROF YONGHOON LEE
Assistant Professor of Management

"There is a trade-off between whether you are going to make sure you have continuous work or take higher risks and try to innovate. I found the networks that are pertinent for each side of the trade-off are quite opposite in K-pop as well as in other industries," Prof Lee said. Thus, the art in career progression is to know when to switch from closed to open networks.

Further research by Prof Lee, who joined HKUST in 2015 following a PhD at INSEAD in France, has also shed light on understanding the type of reputation you want to cultivate: commercial or artistic, in the creative industry context. In the contemporary visual art world, he found a strong segregation between those exhibiting in museum space, selected for their artistic quality, and commercial galleries, which had greater freedom to be more speculative than the former. The message from his research is that building a good reputation alone is not enough. That reputation needs tailoring for a particular audience.

Human nature dictates that there is no escaping the importance of networking in the world of work. "We are basically social animals. We need the resources that we don't possess, including both instrumental and emotional support from human social interaction," Prof Lee said. A successful career hinges on how well people can manage their networks appropriate for the stages of their career.

Many make use of extensive social networking in the virtual world as a shortcut. But Prof Lee said these media forms would not replace real social interaction for career progression. "Social networking sites are overrated in bridging the gap between insiders and outsiders. If anything, they may even increase the gap between those who are in and those who are out," he said.

Prof Lee has published in prestigious journals such as the *Academy of Management Journal*.

URBAN SUSTAINABILITY

In the face of climate change, expanding cities and limited resources, effective use of land and water infrastructure is critical to the sustainability of our metropolises

ON SAFER AND SUSTAINABLE GROUND

The University's geotechnical researchers are global leaders in the theory and engineering of unsaturated soil mechanics, slope stability, mitigation of landslide risk, and risk assessment of multi-hazards

While residing in our rapidly expanding cities is often likened to living in a concrete jungle, few recognize that 99.99% of man-made structures are actually supported by natural geomaterials, such as soil and rocks. Unsaturated soils, covering most of the Earth's land surface, are one such type of geomaterial and, like other geomaterials, their behavior and properties are highly complex, since they are path-dependent (resembling our upbringing and history), stress-dependent, and strain-dependent. These soils are also prone to external loads, such as earthquakes, rainfall, and changes in temperature and humidity. Such loads can cause the soils to expand or contract and potentially collapse, making them hazardous to the natural and man-made structures they support. Understanding these intricate soils is therefore challenging but essential if we are to achieve sustainable development and enhance the mitigation of natural and human-induced disasters.

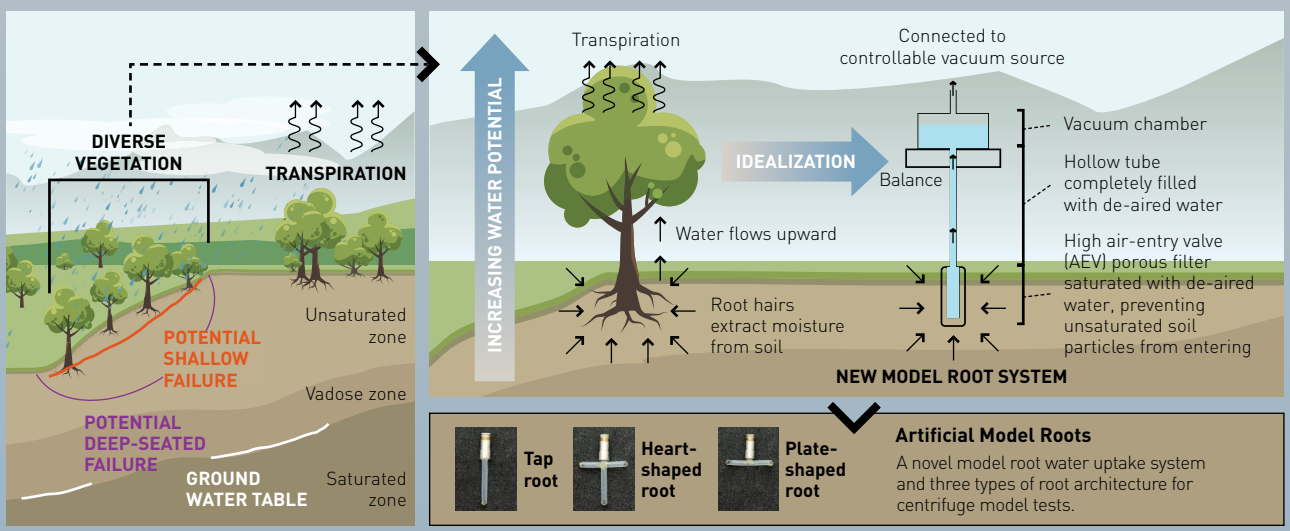
> "Soils are highly complex and varied, just like people, and offer a cornucopia of knowledge for someone with a curious mind"

PROF CHARLES WW NG
CLP Holdings Professor of Sustainability,
Associate Vice-President for Research and Graduate Studies,
President of the International Society for Soil Mechanics and Geotechnical Engineering

Getting to the Root of Unsaturated Soils

Over the past two decades, Prof Charles Ng has taken up the challenge posed by unsaturated soils. He has advanced fundamental knowledge and practice related to slope stability and maintenance, as well as debris flows, a type of fast-moving landslide. In Hong Kong alone, there are tens of thousands of man-made and natural slopes. Recognizing early that these geomaterials needed further exploration, Prof Ng established the unsaturated soil research group at HKUST in 1995 and started the first postgraduate courses on unsaturated soils in Asia the following year. They have gone on to develop a series of theoretical state-dependent elastoplastic frameworks for unsaturated soils, which have become the theoretical basis for experimental and further theoretical studies by researchers globally. Unlike previous

Green Slope Engineering



The roots of plants grown on natural and man-made slopes offer an elegant solution to stabilize slopes. They help to provide both mechanical anchoring as well as soil suction via transpiration to reduce water infiltration, and increase shear resistance to potential failure.

theories of unsaturated soil mechanics, these trend-setting frameworks enable researchers and engineers to simulate interaction among cyclic mechanical, hydraulic (water content and suction), and thermal (temperature) behavior of unsaturated soils in different states and stress-, path-, and strain-dependency.

To verify this theoretical work, Prof Ng's research team has developed and patented novel experimental apparatuses, including a suction-controlled stress-controllable pressure plate extractor, and a temperature-controllable cyclic triaxial apparatus equipped with a novel double-cell total volume measuring system, known as the "HKUST Inner Cell". This has been licensed to a UK company and nearly 200 universities and research institutions worldwide have adopted the plate extractor and the HKUST Inner Cell, the latter of which is now among the standard measuring methods globally.

Nature's Engineers

Based on such in-depth knowledge of the properties and behavior of unsaturated soils, Prof Ng and his team have gone on to make a series of innovative research contributions to slope stability and sustainability. One such area is soil-plant-atmospheric interactions and bioengineered live cover systems. The researchers discovered that not only do plant roots provide mechanical reinforcement, but more importantly, they also induce soil suction via transpiration (hydrological effects), increasing soil shear strength and reducing water infiltration in slopes and landfill covers. "Plants are intelligent natural 'engineers'," Prof Ng noted. "They can cost-effectively stabilize man-made structures and natural slopes, and contribute to the development of environmentally friendly and sustainable cities."

Through this and related discoveries, the team then developed and patented an innovative artificial model root system. The new system used HKUST's world-class geotechnical centrifuge to simulate both the mechanical and hydrological (suction) effects of different types of root architecture and hence their impact on induced soil suction and slope stability.

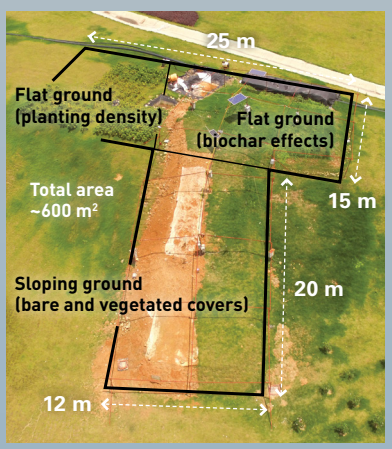
The research group was the first to identify possible types of slope failure involving different types of root architecture. They also derived new analytical solutions to calculate plant-induced soil suction by different root architecture to predict the stability of vegetated soil slopes. With this understanding, the HKUST team could advise on the type of vegetation to plant to increase slope stability in what they called "green slope engineering". In addition, the researchers identified plant characteristics of geotechnical value. Through measuring the leaf area index, for example, engineers could estimate induced suction in the ground and hence analyze slope stability. The research was supported by two multidisciplinary Collaborative Research Fund projects in Hong Kong and a National Basic Research Program (973 project) in Mainland China.

Eco-friendly **Three-layer Landfill Cover**

Hong Kong's landfills are filling up faster than expected. The amount of waste in the city's overflowing landfills has increased by 80% in the past 30 years, with a large percentage coming from the construction sector.

Based on advanced unsaturated soil mechanics, Prof Ng's research team has invented and patented a new environmentally friendly three-layer landfill cover system to protect the environment from gas emissions from the landfill body and to minimize water infiltration into the waste after closure of a landfill. This type of landfill cover system has since been extended to use construction waste as cover materials. No artificial materials, such as geo-membranes, are needed to minimize rainfall infiltration and gas emissions from the landfill. The elimination of artificial, non-environmentally friendly geo-membranes can also prevent interface failure of a traditional landfill cover system.

Unlike traditional soil cover systems, the HKUST system is suitable for all weather conditions. It is self-regenerative, durable, and virtually maintenance free.



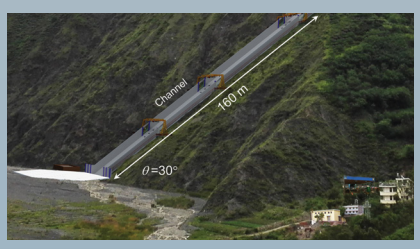
Landfill Cover Composition

Trial at Shenzhen, Xiaping landfill site
A schematic of the novel three-layer landfill cover system using recycled crushed concrete (above) and the field trial using recycled waste at the Xiaping landfill site in Shenzhen, China (left). Recycled crushed concrete is both practical and cost-effective, widening potential interest in both developing and developed countries.

Mitigating Debris Flows with Multiple Flexible Barriers

In addition to green slope engineering initiatives, Prof Ng has now set out to add to global understanding of natural terrain landslides and mitigation measures through a cutting-edge investigation into the interaction between debris flows and multiple flexible barriers. Such barriers are especially useful solutions for densely-populated, hilly cities, for example Hong Kong, and for protecting inter-city infrastructure, such as roads and railways, across mountainous regions, for example Belt and Road initiative countries.

In 2016, Prof Ng brought together a multidisciplinary international research team to launch the five-year project, funded under the Theme-based



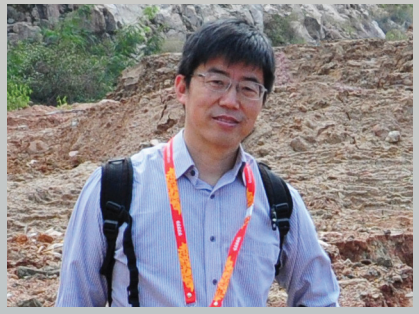
The world's largest man-made 160-meter long flume in Kunming, Mainland China. This facility has a channel width of six meters and will be able to simulate debris flow volumes of up to 500 m³.

Research Scheme of the Hong Kong Research Grants Council. The project will develop the world's first scientifically based design guidelines for multiple flexible barriers. Flexible barriers can undergo large deformation, which is ideal for dissipating high-impact energy. Advantages of using multiple flexible barriers include their constructability, enabling designs to conform to complex mountainous terrain, their ability to blend into the natural surrounding environment, and lower cost.

Facilitating the research is a specially constructed world-leading 160-meter long flume facility in Kunming, Mainland China – part of a collaborative research effort between HKUST and the Chinese Academy of Sciences' Institute of Mountain Hazards and Environment. The flume will play a key role in revealing fundamental mechanisms of interaction between fast-moving landslides and multiple flexible barriers. To complement these large-scale flume tests, the researchers have developed the world's first geotechnical centrifuge model package which is capable of simulating flexible barriers for centrifuge testing. Work in the project's first year has already made an impact internationally, with Prof Ng and his team awarded a Telford Premium Prize in 2017 from the UK's Institution of Civil Engineers and an R.M. Quigley Award (Honourable Mention) by the Canadian Geotechnical Society for their papers on debris flows. The former prizes are awarded annually to work that is judged by peers to be of exceptional quality and benefit to those involved in civil engineering, construction, and materials science, while the latter awards are given to selected papers out of 296 published in the *Canadian Geotechnical Journal* in 2016.

Prof Ng has published some 250 articles in leading geotechnical journals and is the first author (with co-author Dr Bruce Menzies) of *Advanced Unsaturated Soil Mechanics and Engineering* (CRC Press 2007). Prof Ng was elected as the President of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) in September 2017, becoming the first in Greater China to hold this position in the 91 member societies, over its 80-year history.

QUANTIFYING THE RISKS OF LANDSLIDES AND CHAIN REACTIONS



> "Geotechnical multi-risk assessment is an emerging area of focus and we are among the few institutions working on the science"

PROF LIMIN ZHANG
Professor of Civil and Environmental Engineering

Further innovative research in relation to mitigation of landslides and debris flows is ongoing at HKUST in the complementary area of quantitative multi-risk assessment, an emerging field in which the University's geotechnical engineering researchers are taking the lead locally and globally. When landslides and debris flows occur, one of the biggest risks is that they are not isolated events. The aftermath and chain reactions that can follow may in fact cause the greatest damage. As an example of the complexities facing researchers in assessing such hazards, Prof Limin Zhang cites the real-case scenario of a building impacted by the 2008 Sichuan earthquake, next by a landslide behind it, then by flooding and repeated debris flows. "Previously, as a civil engineer, vulnerability would be viewed as different levels of injury to a person or damage to a building. But when we face multi-hazards and their interactions, vulnerability becomes a very difficult issue," he said.

Prof Zhang is a global expert on engineering risk assessment and

Timeline of the Multi-hazards Caused by the Wenchuan Earthquake in Sichuan

BEICHUAN TOWN
Timeline of the multi-hazard scenarios that affected Beichuan following the Wenchuan earthquake
Engineering Geology 180, 4-20 (2014)

EPISODE 1
Wenchuan earthquake; collapse of buildings

EPISODE 2
Landslides; rock avalanches

Po Shan Road,
Mid-Levels, Hong Kong,
18 June 1972.

mitigation. In the past 10 years, he has focused on geotechnical multi-risk assessment. This builds out from traditional risk assessment and management to explore sequential or concurrent hazards and their interactions, issues not previously addressed in Hong Kong or around the world. Often working together with Prof Charles Ng on slope stability projects, Prof Zhang seeks to improve rational engineering decisions and management in relation to landslides and debris flows and in line with the needs of Hong Kong and Mainland China. A personal motivation to drive forward the field was fueled by the aforementioned earthquake in Sichuan, where he had previously lived and had relatives involved in the disaster.

Novel Analytical Framework

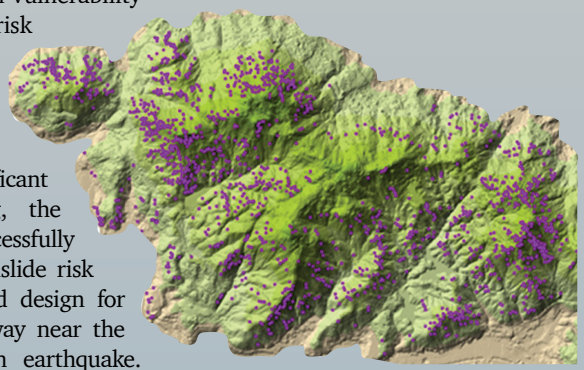
The work of Prof Zhang's research team encompasses full-process multi-hazard numerical modeling, centrifuge modeling, remote sensing, data analytics utilizing Bayesian networks and Monte Carlo risk analysis simulations, development of risk management engineering frameworks, and the application of mitigation measures to different geotechnical and structural engineering scenarios.

To advance knowledge and practice, Prof Zhang and his team have established a novel multi-hazard risk analysis framework known as the HKUST five-step method: definition of scale and initiating events; identification of the multi-hazards and their interactions; interactions of elements at risk (human, property); multi-vulnerability assessment; and multi-risk assessment.

Hazard Mitigation in Action

In a particularly significant project for Prof Zhang, the HKUST method was successfully utilized to provide a landslide risk assessment and risk-based design for rebuilding a major highway near the epicenter of the Sichuan earthquake. A landslide warning system was also installed to reduce risk once the highway began operating.

Locally, Prof Zhang and his team are investigating the potential impact of cascading landslide hazards on Hong Kong Island under extreme storms brought about by climate change. Supported by the Hong Kong Research Grants Council, the Collaborative Research Fund project seeks to develop a unique stress-testing framework to assess slope safety and system response, improvements and management strategies. Project collaborators include the Hong Kong



Western Hong Kong Island suffered 1,600 landslides between 1924 and 2009.

Advancing Culture of Living with Landslides, 2, 17-32 (2017)

EPISODE 3
Flood from breaching of Tangjiashan Landslide Dam

EPISODE 4
Debris flow from landslides in Beichuan County

EPISODE 5
Change of river course; river scour

Old town ruins of Beichuan flooded due to rising riverbed; long-term evolution of hazards; future hazards

government's Geotechnical Engineering Office and Hong Kong Observatory.

In addition, Prof Zhang is working on expanding such stress-testing to cover Hong Kong's entire 1,100 square kilometers by building a high-resolution digital platform to simulate further low-probability, high-consequence risk scenarios, including severe flooding, landslides, debris flows and other intense hazards. He later hopes to extend this to the wider Guangdong - Hong Kong - Macao bay area, with its twin dangers of river flooding and storm surges.

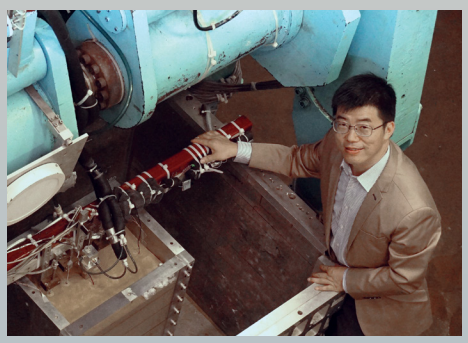
Boost for Decision-makers

"As societies develop, public tolerance of damage decreases and is replaced by a general expectation of safety," Prof Zhang said. His research is thus in line with the greater need for social and political leaders to be accountable, should disaster strike, and such leaders' increasing reliance on quantitative risk-based assessment to explain the decisions made. In other words, a way to help everyone expect the unexpected through science.

Prof Zhang has published more than 200 international journal papers and is co-author of *Dam Failure Mechanisms and Risk Assessment* (Wiley 2016). He is also Editor-in-Chief of *Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards* (Taylor & Francis).

Centrifuge Generates **Ground-shaking Impact**

Prof Charles Ng's research group comprises students from 16 different nationalities.



Prof Limin Zhang uses the four-axis robotic manipulator installed on the centrifuge, capable of creating an elevated gravity field 150 times that of Earth's gravity for static model tests.

The HKUST Geotechnical Centrifuge Facility (GCF), set-up in 2001, was the first in the world to be equipped with a bi-axial shaking table for geotechnical earthquake engineering and a state-of-the-art four-axis robotic manipulator. The equipment gave HKUST researchers a competitive edge in carrying out advanced physical modeling of numerous engineering-related problems. The centrifuge has played a key role in attracting major research projects funded by large-scale grants such as Theme-based Research Scheme and Collaborative Research Fund, and advancing world-class geotechnical engineering research within the University and beyond. Prof Charles Ng was the Director since its official opening; under his 14-year leadership, the GCF remains a state-of-the-art leading centrifuge facility in the world. Prof Limin Zhang is the current Director.

HKUST Five-phase Multi-hazard Risk Analysis

PHASE I: DEFINITION

Define the source of risk, location and potential initiation (e.g. earthquake or rainfall). Then, investigate individual hazard lifecycles and the space scale that each hazard has evolved over its lifecycle.

PHASE II: MULTI-HAZARD ASSESSMENT

Identify lead hazards (e.g. landslides or rock avalanches) and derived hazards (e.g. debris flows or river sedimentation) and investigate cascading effects and temporal and spatial evolution of hazards.

PHASE III: INTERACTIONS AMONG ELEMENTS AT RISK

Identify elements that may be at risk and consider methods to resolve potential problems caused. For instance, consider rerouting traffic following a landslide that causes highway or road blockage.

PHASE IV: MULTI-VULNERABILITY ASSESSMENT

Analyze interactions between vulnerabilities (e.g. human or structural vulnerabilities) and hazards.

PHASE V: MULTI-RISK ASSESSMENT

Draw up assessment that calculates all possible risks from multiple hazards in a defined area, including overlapping and non-overlapping risks, risks from amplification and number of zones affected by root hazards, as well as overlapping hazards and derived hazards.

SMART SOLUTIONS FOR WATER MANAGEMENT

Knowledge breakthroughs are building platforms for technologies that can assist eco-friendly water quality management, reveal problems in pipelines, and revolutionize wastewater treatment

Back in the swim after Hong Kong's major harbor cleanup. Hong Kong has a compact urban area yet also encompasses a 700-kilometer coastline and 1,700 square kilometers of diverse marine waters, which have served as a "big laboratory" for testing designs and solutions to mitigate many water pollution issues arising from the city's industrialization and population pressures.

Photo: Sam Tsang / South China Morning Post

Fragrant Harbor 2.0

Cities are already home to 50% of the global population. Within two decades, this figure is expected to rise to 60%, or five billion people. Mitigating the impact of urban activities on the hydrosphere – oceans, seas, lakes, rivers, and other water bodies – and the monitoring and management of municipal water systems are major concerns for a sustainable future. Water pollution control in densely-populated coastal cities is a particularly challenging task that demands innovative technology, as the coastal waters in such urban settings typically have multiple beneficial uses.

Hong Kong has proved a significant location for water environmental engineers to contribute globally to understanding and technologies related to the environmental hydraulics involved in such issues. The city's spectacular harbor (the name Hong Kong means "Fragrant Harbor" in Chinese) and many beautiful beaches have been a focus of attention, with the community goal of cleaning up the water pollution problems left over from its past role as the world's workshop from the 1960s to 1980s and sewage treatment needs of its rapidly rising population.

Fathoming Buoyant Jets

For Prof Joseph Lee, the first Asia-based academic to receive the Hunter Rouse Hydraulic Engineering Award from the American Society of Civil Engineers, the theoretical understanding and mathematical modeling of the mixing of buoyant jets has been a core area over his 35 years of research.

Natural and polluting discharges in the environment exist as buoyant jets – wastewater effluents from cities and industry, thermal discharges from power stations, virus-laden plumes in the atmosphere, and hydraulic jets in civil engineering structures. The effluent discharge is mixed by the turbulent vortices in the environment, leading to a continuous and rapid reduction in pollutant concentration. Predictive modeling of buoyant jets provides a basis for environmental management and control, enabling impact and risk assessment, definition of mixing zones, the design of advanced effluent diffusion systems to meet water quality objectives, real time water quality management (for example, control of disinfection dosages), and public engagement for better understanding of the impact of infrastructure projects.

But it is a hugely complex task. How to forecast the mixing and turbulent vortices generated when, for example, a discharge of treated sewage is expelled into a tidal current or moving seawater (described as a buoyant jet because fresh water is lighter than seawater and the discharge has momentum)? And to predict turbulent buoyant shear flow not only for one buoyant jet but for hundreds of interacting buoyant jets?

World-leading Predictive Modeling

In seeking to expand such understanding, Prof Lee has contributed a rigorous body of knowledge to the fluid mechanics of buoyant jets, publishing over 40 articles in leading international journals to date and authoring *Turbulent Jets and Plumes – A Lagrangian Approach* (Springer 2003).

Prof Lee and his team have also developed powerful tools to assist global research and practice in this area, including the JETLAG mathematical model to predict the initial mixing of an arbitrarily inclined buoyant jet in a current over a wide range of environmental conditions. From this, the researchers went on to develop VISJET computer ocean outfall modeling and visualization software.

> “How you formulate a problem is very important in engineering. We don’t make a problem more complicated than necessary. We take a complex issue and find a simple way of solving it effectively”

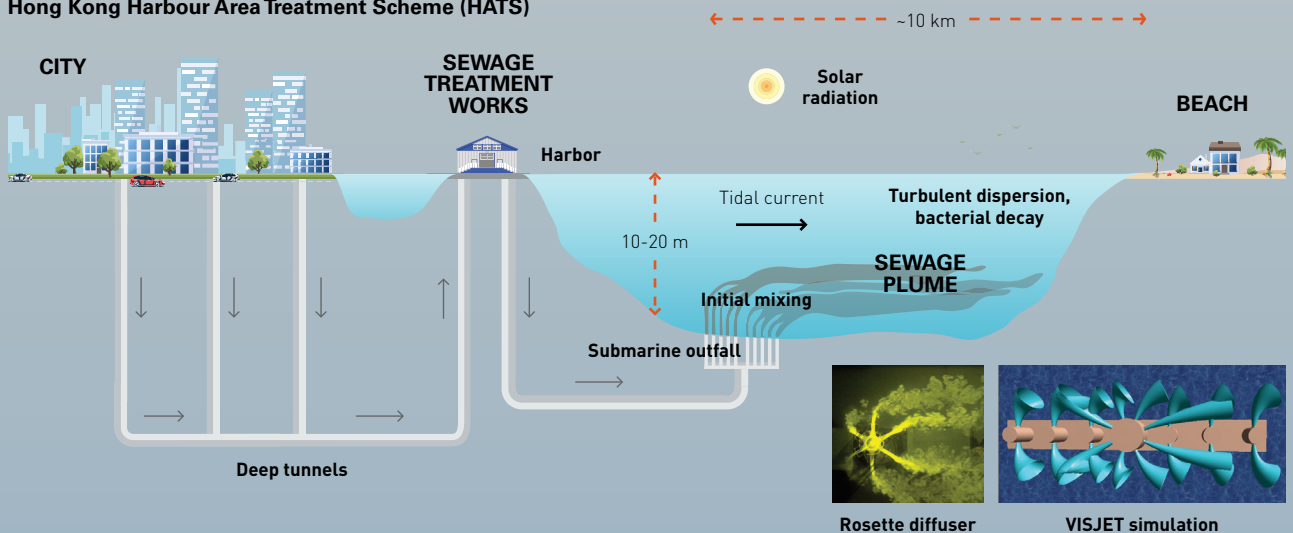
PROF JOSEPH HUN-WEI LEE
Elman Family Professor of Engineering and Public Policy

JETLAG/VISJET, now in use in 50 countries, is the only model in the world that integrates accurate predictions of multiple jets with three-dimensional trajectories, including multiple plume merging and interaction, and advanced visualization technology. It is particularly suited for application in the heavily utilized shallow coastal waters in Asia. The related basic research received a prestigious 2010 State Scientific and Technological Progress Award (Second Class) from China's State Council.

Treated Effluent, Chlorine Optimization

More recently, Prof Lee and his researchers have utilized their expert knowledge of buoyant jets to tackle a complex problem involving chlorination of treated effluent. Since 2010, the treated effluent at Hong Kong’s Stonecutters Island Sewage Treatment Works, the world’s largest chemically enhanced centralized primary treatment (CEPT) plant, has been disinfected by chlorination to reduce the bacterial (*E. coli*) level and protect the water quality of nearby bathing beaches. The plant serves a population of around 3.5 million, with a daily average sewage flow of 1.8 million

Hong Kong Harbour Area Treatment Scheme (HATS)



Sewage from 3.5 million people is conveyed to Stonecutters Island Sewage Treatment Works, the largest of its kind in the world, via a 23.6 km-long deep tunnel system and is centrally treated by chemically enhanced primary treatment (CEPT). The treated effluent is discharged into the harbor in the form of multiple rosette buoyant jet groups from an ocean outfall. VISJET provides a realistic simulation for the trajectory and dilution of such a complex diffuser. Bacteria/pathogen loads are carried in the trapped sewage plume below the surface (in summer stratification) and transported by the tidal current while undergoing turbulent mixing and decay before arriving at a bathing beach.

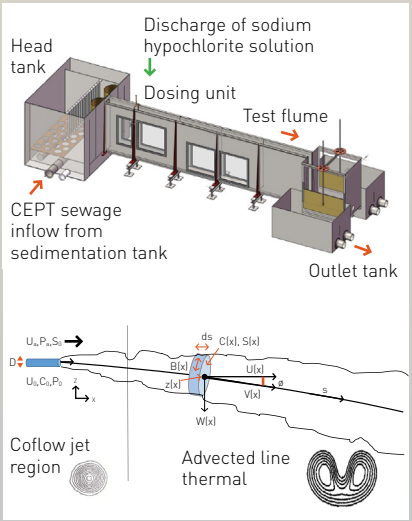
cubic meters collected through a deep, 23.6 kilometer system of tunnels.

Inside the treatment plant, high concentration chlorine (10%) is injected into a "flowing river of treated sewage" in the form of multiple dense jets. While chlorine is an effective disinfectant for reducing pathogen levels, it is toxic to the marine environment and aquatic life. Actual operation shows that the chlorine concentrations fluctuate in a complex manner, and a good part of the chlorine is consumed by organics in the sewage rather than killing the pathogens. This is both costly and environmentally unfriendly.

To study the challenging problem, Prof Lee and his team designed and constructed a full-scale hydraulic model at the Stonecutters plant. "At the end of the day, the best theories have to face the test of reality. You can't just talk about principles," he said. "That's really what engineering is all about – integration of theory and practice."

Findings have recently been reported in the *Journal of Environmental Engineering* in which Prof Lee outlines a theory for the mixing and chemical reaction of a chlorine jet with CEPT effluent, explains the puzzling chlorine consumption, and proposes various chlorine optimization strategies.

Prof Lee has served as expert consultant on numerous hydro-environmental projects and contributed to the design of several major urban environmental management and flood control infrastructure in Hong Kong, including the Tai Hang Tung Storage Scheme, Yuen Long Bypass Floodway, and the Hong Kong West Drainage Tunnel.



Top: The field-scale model at Stonecutters Island Sewage Treatment Works for studying chlorine dosage optimization in Hong Kong's wastewater.

Bottom: Theoretical model of dense chlorine jets in sewage flow for dosage optimization.

A Good Day to **Go to the Beach?**

The WATERMAN coastal water quality forecasting and management system, masterminded by Prof Lee, has provided a new way of dynamically coupling near and far field models using a Distributed Entrainment Sink Approach (DESA). This has enabled a robust and seamless simulation of the transport and fate of pollutants from the point of discharge to sensitive receivers (for example, bathing beaches) located kilometers away.

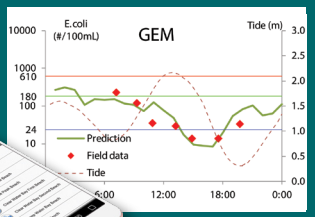
In practice, the WATERMAN system has become the first to predict coastal beach water quality in real time, with field validation, providing daily water quality forecasts for 16 Hong Kong beaches through the internet and a smartphone app. Based on statistical and 3D deterministic hydrodynamic and water quality models, it has achieved over 80% accuracy in forecasting compliance/exceedances with Hong Kong's Water Quality Objectives.

In addition, WATERMAN enhanced communication, decision-making and emergency response through the development of a 3D environmental impact assessment system using hydro-environmental modeling and visualization technology; and took forward scientific management of fisheries through providing a prediction of the carrying capacity of Hong Kong's 26 fish culture zones.

The project, funded by the Hong Kong Jockey Club Charities Trust, was awarded to Prof Lee in 2009 while at the University of Hong Kong. He continued to pursue the research after moving to HKUST in 2010, with a trial system becoming accessible to the public in 2011. Related publications have appeared in the *Journal of Fluid Mechanics*, *Water Research* and *Journal of Environmental Engineering*, among others.

Deep Water Bay

Big Wave Bay



The WATERMAN system provides a daily forecast of beach water quality, disseminated to the public through the internet and a smartphone app.

IN THE PIPELINE

> “Ultrasound imaging is based on sending waves into a patient’s body and measuring the echoes. We want to do that with pipelines. We want to send acoustic waves in the fluid in pipes, capture the echoes, and use them to diagnose the health of the pipe system”

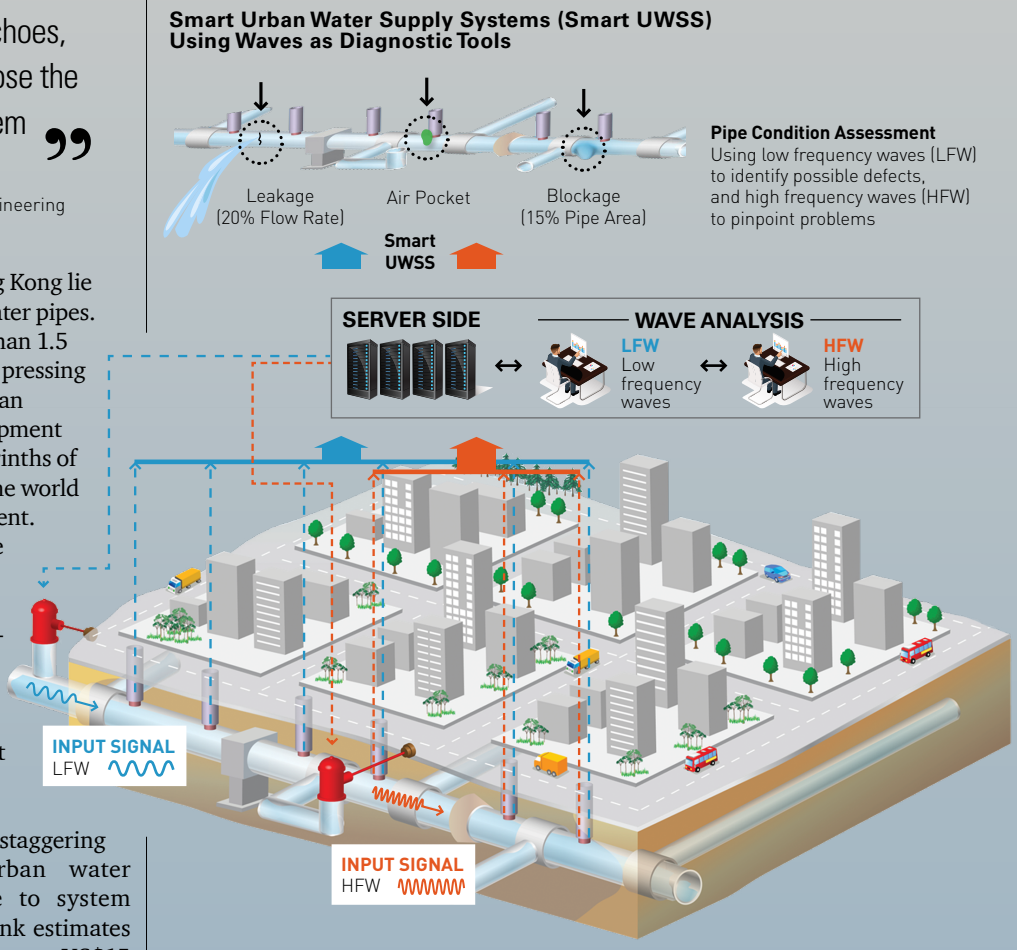
PROF MOHAMED GHIDAOUI
Chinese Estates Professor of Engineering

Beneath the streets of Hong Kong lie over 7,500 kilometers of water pipes. In the US, there are more than 1.5 million kilometers. What is pressing for the sustainability of urban lifestyles and future development is that these immense labyrinths of pipelines in cities around the world are often aging and inefficient. Leaks and bursts contribute to business losses, social disruption, and require expensive renewal strategies – if they can be afforded. (The Hong Kong government recently completed a 15-year project replacing 3,000 kilometers of pipes at a cost of over HK$23 billion.) Globally, a staggering 30%-40% of piped urban water is wasted annually due to system deficiencies and World Bank estimates place the cost of water loss at US$15 billion each year.

Pressure Wave Potential

Prof Mohamed Ghidaoui, an expert in hydraulics and fluid mechanics, is now tackling these issues through visionary research with the potential to take urban water supply systems to the next level of efficiency, cost-effectiveness, and sustainability. Prof Ghidaoui is seeking to harness understanding of the propagation and reflection of pressure waves in pipelines to build a “smart”, pioneering real-time diagnostic management platform. The “smart” platform will utilize sensors in pipes and wave-based techniques and technologies to allow engineers to continuously monitor the health of underground water systems and rapidly pinpoint and anticipate pipeline problems, in a non-disruptive and non-intrusive manner.

In water systems, the simple action of starting a pump, or opening and closing a valve, causes pressure waves. Traditionally, these waves have been seen as detrimental to conduits and most engineering efforts to date have focused on ways to mitigate or suppress them. However, from his accumulated research findings over the past 20 years, Prof Ghidaoui is focusing on the beneficial outcome of pressure waves – pipeline diagnostics. In a similar way to a doctor conducting an ultrasound scan in a clinic, waves could be used as tools to “image” conduits and, from analysis of the resulting data, find and characterize system defects, such as leaks, blockages and pipe deterioration. Being fast (pressure waves travel at one kilometer per second) and non-intrusive (waves can be sent to sample a large area of pipeline from just one location), such tools would also facilitate system-wide diagnosis and be applicable to most faults.



The bottom plate depicts a section of a pipe system under roads and buildings; its state and condition are unknown. Pressure waves are generated in the pipes by a pump, valve, or piezo-electric transducer and travel rapidly through the pipelines at a speed of one kilometer per second. These pressure waves are picked up by sensors in the pipes, and the data is wirelessly transmitted in real-time to the base-stations, where it is transformed into sharp images showing the state of the system, providing valuable information for analysis of pipe defects e.g. blockages, leaks, and weak pipes.

Fluid Mechanics Meets Signal Processing

Conventional pipeline diagnostic systems possess certain limitations, with good reason – pipes are buried deep underground, out of sight and difficult to access. Current technology only covers a short range (200 meters or less), produces low-resolution data, targets specific faults, and is unable to forecast problems. These critical limitations call for a new diagnostic paradigm for water supply network monitoring and fault detection. However, establishing a proactive "wave" diagnostic platform is no simple feat. It will involve complex physics and mathematics, a highly dynamic environment encompassing a "web of pipes", numerous active devices and flow controls, noise from turbulence, traffic, construction activities, and random flow demands.

Overcoming these issues is now the focus of a groundbreaking inter-disciplinary Theme-based Research project, led by Prof Ghidaoui and supported by Hong Kong Research Grants Council. The Smart Urban Water Supply Systems initiative is a pioneering undertaking involving an international group of leading researchers from Hong Kong, Mainland China, North America, Europe, and New Zealand, together with the Hong Kong government's Water Supplies Department. The team brings together engineering experts in hydraulics and fluid mechanics, signal processing and wireless communications and structural mechanics as well as mathematicians.

The researchers are currently studying sensing of actively generated fluid waves traveling at high speed in pipelines and how to use the electronically captured wave echoes to "image" and diagnose the pipes. Theories are being evaluated in the lab at HKUST and in field studies in Hong Kong's urban area. A pilot-scale demonstration experimental test bed has also been developed in Beacon Hill, Kowloon, Hong Kong. Findings can crucially contribute to the sustainable development of Hong Kong through water conservation and locally developed innovation and technology. However, the focus is not solely on Hong Kong but on a system that will work anywhere in the world.

Prof Ghidaoui has published in leading journals such as the *Journal of Hydraulic Engineering*, *Journal of Fluid Mechanics*, and *Journal of Hydraulic Research*. In 2007, he received the Arthur Thomas Ippen Award, the highest honor presented by the International Association for Hydro-Environment Engineering and Research (IAHR). He now serves as Editor-in-Chief for the *Journal of Hydraulic Research*, IAHR.

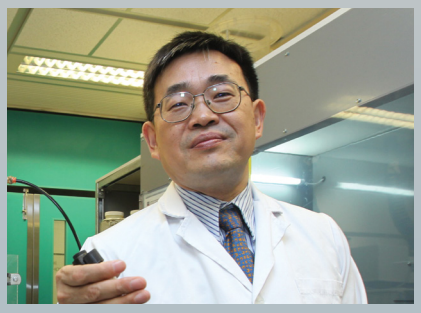
FROM SLUDGE TO SANI

Sewage sludge is a growing worldwide problem, as established cities deal with expanding populations and new urban areas spring up in developing economies requiring efficient treatment for sanitation. Conventional plants utilize biological processes that convert around 60% of the organic carbon in sewage to carbon dioxide and the remainder to sewage sludge. Such sludge is then disposed of in landfills or incinerated, contributing to greenhouse gas emissions and using up energy.

Seawater Change

Prof Guanghao Chen and his team have been working on the problem since 2004, studying the connections between seawater, sulfate and sludge, leading to the transformational SANI municipal wastewater treatment process that is generating opportunities for a cleaner environment through innovative ways to deal with "dirty water".

SANI launched a full-scale trial at Hong Kong's Shatin Sewage Treatment Works in the summer of 2014.



> "Urban sustainability to me means the three Rs: reduce, recover, and reuse"

PROF GUANGHAO CHEN
Chair Professor of Civil and Environmental Engineering

SANI stands for Sulfate reduction Autotrophic denitrification and Nitrification Integrated process, or "sludge killer" in Chinese. The original platform stems from a happy confluence: Hong Kong's use of seawater for flushing as an alternative to fresh water (it is one of the few places in the world to do so and is the result of a historical initiative to mitigate the city's lack of water resources); and Prof Chen's investigations into the potential of sulfate to reduce the sewage sludge produced from conventional wastewater treatments.

Three-wheel Cycle

The traditional two-wheel organic oxidation and nitrification biochemical reaction using the integrated carbon and nitrogen cycle employs microbes to convert organic pollutants into carbon dioxide and clean up sewage. However, such microbes grow rapidly through this process, creating large amounts of unwanted sludge as a by-product. The novel three-wheel integrated cycle proposed by Prof Chen employed slow-growing sulfate-reducing bacteria and sulfate in seawater together with nitrification to oxidize and eliminate pollutants. The method proved highly viable in lab and pilot testing, reducing oxygen needed for organic matter removal and minimizing sludge generation. From 2007 to 2010, a pilot test plant at Tung Chung Sewage Pumping Station in Hong Kong showed a 90% sludge reduction at a capacity of 10 cubic meters of sewage per day.

In 2013, with the assistance of Hong Kong government departments,

Prof Chen set up a 1,000 cubic meter sewage demonstration plant that resulted in significant conclusions: 60%-70% reduction in biological sludge, 20% reduction in energy required for treatment and requiring 40%-50% of the space for treatment. Optimization is currently underway to make the process even more compact and effective at reducing sludge, and to ultimately achieve a more energy-saving system.

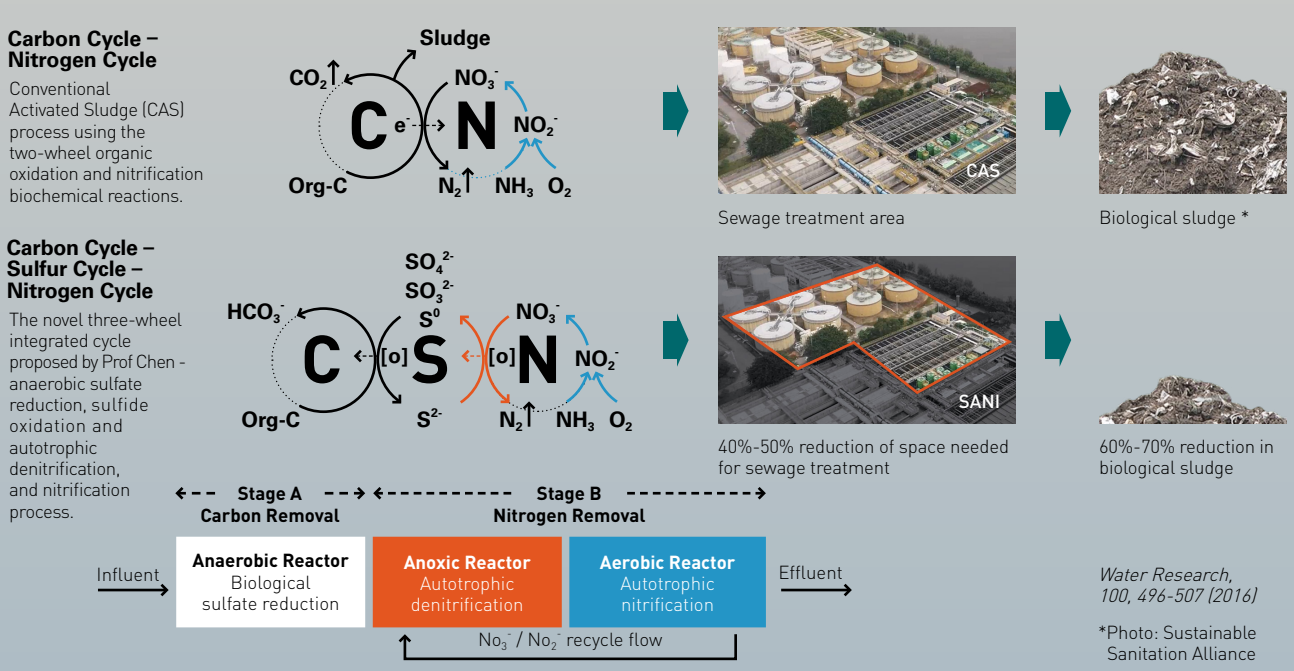
The revolutionary treatment process has brought 19 patents and resulted in over 70 publications and five international awards, including three from the eminent International Water Association. The technology drew interest from the UNESCO-IHE Institute for Water Education, leading to a three-year study involving Prof Chen, the European Union, and a SANI pilot demonstration plant in Cuba. The study, completed successfully in June 2017, highlighted ways to mitigate water scarcity on the island through leading-edge urban water management systems. SANI has also attracted attention from major national and international water and environmental companies.

Recovery Discovery

Exciting extensions to the fundamental SANI platform are now moving forward. Costly materials that normally cannot be synthesized on an industrial scale can be recovered from SANI sludge and two of Prof Chen's students will set up a company to take forward their innovative sludge-to-resource technology that can help realize production of sulfated polysaccharides, a high-valued raw material used in the food and pharmacy industries. The technology won the exhibition award at the 7th Annual HKUST One Million Dollar Entrepreneurship Competition in 2017.

Prof Chen and his research team are also exploring the recovery of phosphorus from human urine. Phosphorus, which is rapidly being exhausted, is an important element for food production through its use in fertilizers. In ongoing research, the team has shown the potential for seawater-catalyzed urine phosphate recovery in a process that adds seawater to hydrolyzed urine, leading to the formation of a valuable phosphorus-containing fertilizer (struvite precipitates). Related research has appeared in *Water Research*.

"Now we have SANI, our goal is to continuously lead the way for space-saving, energy-efficient wastewater treatment and resource recovery through the testing and application of new technologies," Prof Chen said.



Water Research, 100, 496-507 (2016)

*Photo: Sustainable Sanitation Alliance

In the first reactor (anaerobic), sulfate is reduced to sulfide by sulfate-reducing bacteria while organic carbon is oxidized to carbon dioxide (which dissolves as bicarbonate). In the second reactor (anoxic), sulfide is subsequently oxidized back to sulfate by sulfur-oxidizing bacteria while nitrate is autotrophically reduced to nitrogen gas. In the third reactor (aerobic), ammonia is oxidized to nitrate by the nitrifiers. All three functional bacteria are slow growers, i.e. they have very low yields and hence produce minimal sludge.

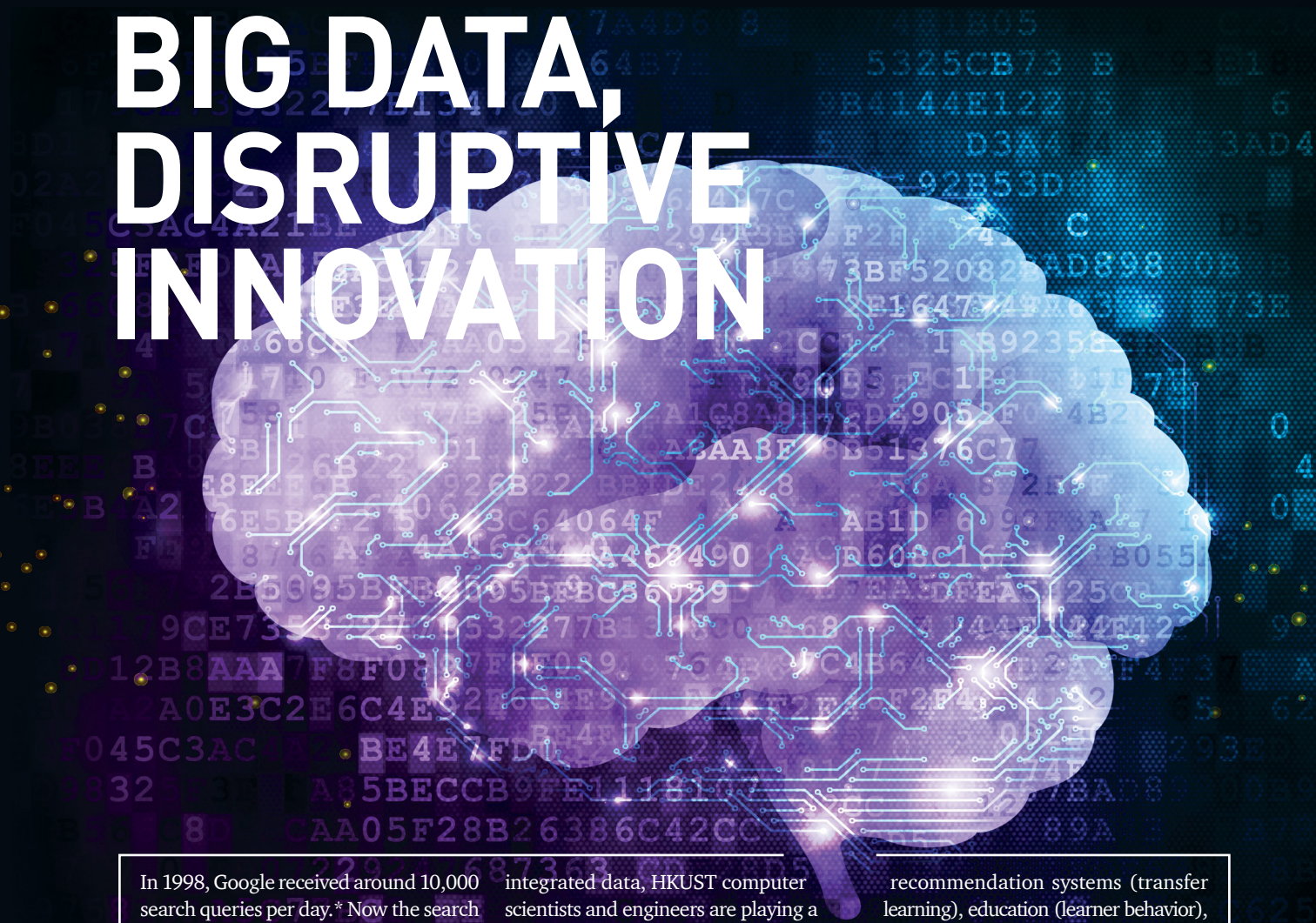
Fresh Links

In 2015, HKUST gained approval from the Ministry of Science and Technology of China to establish a Hong Kong Branch of Chinese National Engineering Research Center (CNERC) for Control and Treatment of Heavy Metal Pollution. The Center is led by Prof Guanghao Chen and encourages collaboration between Hong Kong, Mainland China, and overseas water experts.

The focus is on optimization of water systems and the development of new technologies for adoption by industry to enhance smart urban water and wastewater management, linking to Prof Mohamed Ghidaoui's and Prof Joseph Lee's work on waves in pipelines and turbulent mixing in rivers and oceans respectively. "Our main target is the use of different types of water – saline, brackish water – as alternative water resources to reduce the use of the increasingly precious resource of fresh water," Prof Chen said. "And to develop smarter urban systems in terms of quality assurance and monitoring."

HKUST technologies and applications are enabling the massive amounts of information now being generated to drive forward business and social change

BIG DATA, DISRUPTIVE INNOVATION



In 1998, Google received around 10,000 search queries per day.* Now the search engine handles over 3.5 billion search queries per day or an average of 40,000 every second. Where decision-makers used to rely largely on experience, in today's mega-dataset digital era, huge amounts and varieties of information can be quickly accessed, integrated and analyzed to reveal fresh knowledge and quantitative patterns that widen established perspectives and norms. Traffic jam predictions for bad weather through combining meteorological and transport data, or analysis of Twitter messages discussing illness together with flight information to prevent the spread of diseases are examples.

Through exciting advances in this brave new world of colossal and integrated data, HKUST computer scientists and engineers are playing a major role in bridging the traditional gap between academia and industry practice. The focus of the cutting-edge research at the University and through the HKUST Big Data Institute is to tackle problems with real-world relevance and to collaborate with industry front-runners to turn theory into applications leading to innovative services and new ways of understanding ourselves.

To further develop cognitive computing, researchers are fostering novel insights into artificial intelligence, machine learning, and computer visualization that are extending big data analytics into areas such as the arts and business writing (stylometry and machine reading), retail/consumer recommendation systems (transfer learning), education (learner behavior), and smart city infrastructure (for example, route planning, visitor traffic).

To assist such breakthroughs, HKUST computer engineers are making significant contributions to big data infrastructure support through leading-edge improvements in speed and efficiency. These advances include developments in database query processing and interactive data exploration; and faster communication between machines in the physical data centers that keep search engines and cloud computing in operation.

In doing so, the University's researchers are helping both machines and humans become smarter.

** Statistic Brain Research Institute*

BUILDING INTELLIGENCE

From Numbers to Knowledge

For a person, the ability to recognize and apply knowledge and skills learned in previous tasks to new endeavors is a natural occurrence. After understanding how one card game works, it is easier to pick up another. For a computer, such learning is incredibly hard. This is the specialist domain of Prof Qiang Yang, an expert in data mining, artificial intelligence, machine learning, transfer learning and deep reinforcement learning.

Prof Yang has spent 20 years fathoming algorithms that seek to endow computers with similar capabilities to humans in retaining and reusing previously learned knowledge in order to "think" and "decide" how to extract information and patterns from the rivers of data flooding our digital age. Prof Yang and his team have improved the accuracy of computers' performance through devising versatile frameworks for such "transfer learning". He has developed Instance-based Transfer Learning, which uses individual instances to bridge different domains, and Heterogeneous Transfer Learning, where the computer learns in one knowledge domain (for example, text) then transfers what it has learned to a separate or more difficult domain (for example, images).

Prof Yang has made these frameworks open source, enabling other researchers and the field overall to develop at a faster pace. He was also the first to propose the use of transfer learning in collaborative filtering and recommender systems. Applications have ranged from early online advertising directed at users to improvements in recommendation systems, including a state-of-the-art recommendation system for ICT global giant Huawei's App Store.

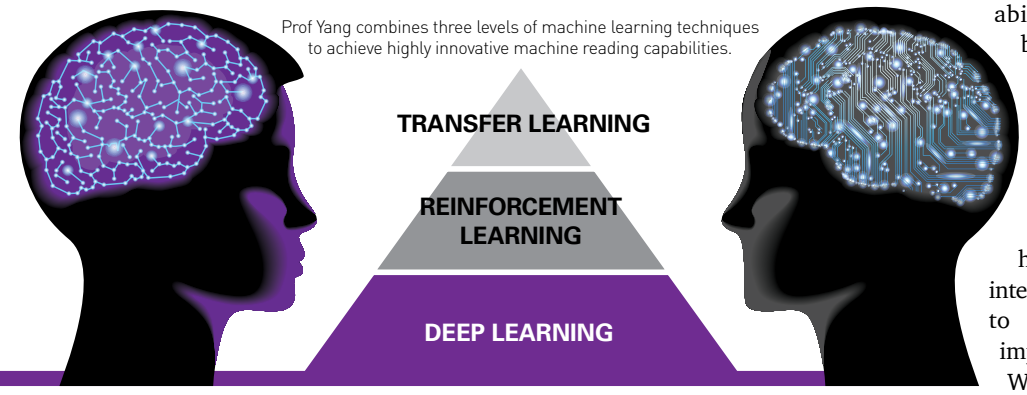
Recent research at the WeChat-HKUST Joint Lab on Artificial Intelligence Technology (WHAT LAB), set up with Mainland China internet giant Tencent in 2015, has inspired a novel application to improve machine reading capabilities. Books, news articles, and blogs are used as input to train a machine learning model that can produce an abstract of such readability that it doesn't appear to have been written by a machine. The objective is to assist people with information overload on social networks or boost company productivity by enabling a computer to develop an abstract of a long report or integrate data and highlight the main points the reader needs to know. By reading books by the same author, the demonstration model designed by Prof Yang and his students has even written a high-quality novel of its own in the writer's style, taking just a few seconds to do so.

In improving such machine reading abilities, Prof Yang's team has become the first to integrate a reinforcement learning algorithm that leverages users' feedback related to positive comments on prior abstracts with transfer learning and deep learning (recurrent neural networks) to help the computer make a more intelligent decision on what abstract to generate. The innovation has improved the quality substantially. With information to hand quicker, it can also speed up report-writing as well as learning.

"The work at HKUST seeks to increase the knowledge we can get from data by making the process of moving from data source to understanding faster and more efficient, accurate and useful to people," Prof Yang said.

> "We are inventors, always thinking of how to use data in a new way"

PROF QIANG YANG
New Bright Professor of Engineering,
Head, Department of Computer Science and Engineering,
Director, HKUST Big Data Institute,
Inaugural Editor-in-Chief of
IEEE Transactions on Big Data



Prof Yang combines three levels of machine learning techniques to achieve highly innovative machine reading capabilities.

Humans have the ability to apply knowledge and skills learned in previous tasks (e.g. cycling) to new tasks (e.g. motorcycling). Prof Yang's transfer learning algorithms help computers to acquire the ability to retain and transfer knowledge from a source domain to a target domain.

> All these charts and visuals are like a movie. The actors are the same, but when you combine them together differently, you can tell a new story

PROF HUAMIN QU
Professor of Computer Science and Engineering

Seeing the Larger Picture

The power of the visual to impart information plays a hugely significant part in our lives, shaping our understanding of the world through "seeing with our own eyes" and through a variety of media, ranging from art over the ages to today's selfies and YouTube videos. Prof Huamin Qu and his team are leveraging such visual impact to mine the digital world of big data, by combining computational power to detect patterns and extract information from vast quantities of data with cutting-edge graphics and virtual reality techniques. In this way, they are uncovering previously unknown relationships, including those related to our own behavior. "We call it amplifying cognition," Prof Qu said.

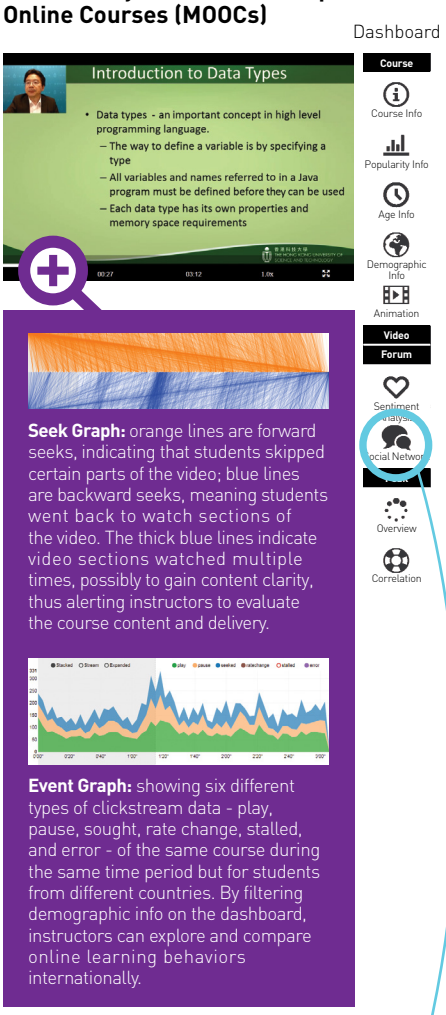
One recent outcome of such data visualization is VisMOOC, the first visual analysis system for discerning e-learning behavior. The intuitive HKUST web app offers fine-grained analysis of video "clickstream" data, drawn from learners watching lectures for Massive Open Online Courses (MOOCs). VisMOOC pinpoints where learners play a section multiple times (indicating difficulty in comprehension), where they pause (to consider or take notes) and what they skip through (lack of interest or not challenging enough), among other details. Such clickstream data are matched with statistics from chat groups (forums), demographics, and grading for assignments and exams. Results are then provided in a novel visual form, labeled a "seek diagram".

Following VisMOOC's success, Prof Qu's team and collaborators are developing an open source platform with advanced visualization interfaces for individual institutions to do detailed analysis on e-learning behavior and course design.

On a wider scale, Prof Qu is integrating cutting-edge visualization with large-scale telecommunications data to create applications contributing to smart city understanding, for example, route planning, crowd management for transportation, analysis of visitor traffic for shopping centers at different times of the day, and even tracking of disease outbreaks. In 2016, such work saw Prof Qu receive the Distinguished Collaborator Award from Huawei's Noah's Ark Lab, the company's long-term, big-impact research lab. Working with WeChat, Mainland China's dominant messenger app, Prof Qu has also solved the challenging problem of visualizing the propagation of information over a large social media network, involving multiple attributes/dimensions and dynamic evolution. Analyzing users' behavior can assist in finding common communication patterns adopted by the public.

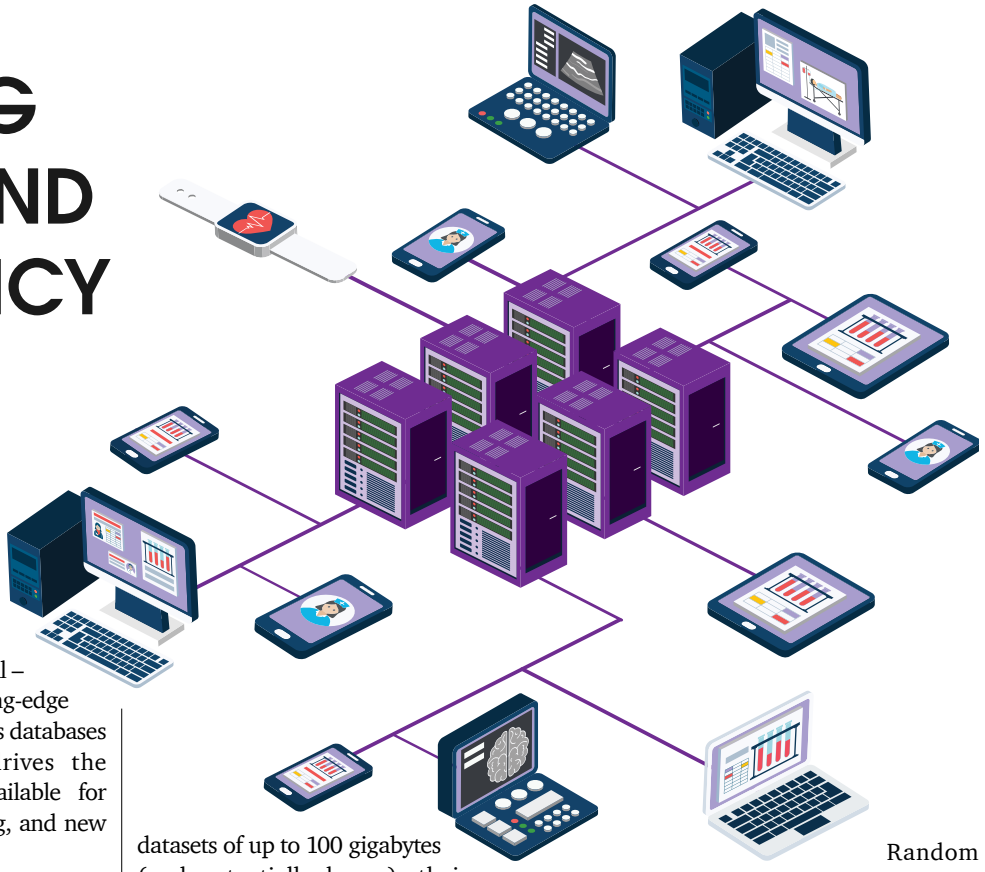
According to Prof Qu, a good visualization design must be effective in serving as a magnifying glass for what the data patterns show, aesthetic and intuitive. In addition, it should not be a pie chart or bar graph but a new visual form that carries interest for the viewer. Such integration of computational power in pattern recognition and mining and human expertise in visual pattern recognition, is a key area for further exploration, he noted. "Many real-world problems cannot be easily formulated as a computer algorithm so we need to keep humans in the loop."

Visual Analysis for Massive Open Online Courses (MOOCs)



Forum Social Network: each dot represents a student. The size indicates the degree of activeness, and the color indicates the grade. The large gray dot shows that the student is active in the forum but does not achieve any score. The visualization gives valuable insight about students and their learning interactions, and provides MOOC instructors with useful information to improve course content.

BUILDING SPEED AND EFFICIENCY



Responding to Queries... Fast

Building intelligence – both human and computational – requires the support of leading-edge big data infrastructure, such as databases and data centers, that drives the fundamental capabilities available for data analysis, decision-making, and new ways of understanding.

Within the realm of digital databases, for example, the keywords are speed, accuracy, and accessibility. These are the criteria that count for data analysts and business users who need to perform analytical queries on a large amount of data with complex conditions and return aggregated results that can enable decisions to be made. For example, a sales director of a company handling millions of transactions per day might be interested to know the total revenue of all transactions for a specific product category in a certain period of time, where the buyer and seller are in specific countries, and the product has parts manufactured in yet another country. Yet, long running times for such analytical queries, even in leading, commercial-level database systems, are still among the major challenges to overcome.

Now Prof Ke Yi, an expert in database systems and algorithms, has solved a problem that has taxed the community for over 15 years, enabling responses to queries to be given in seconds rather than minutes or hours. Prof Yi and his team's novel algorithm allows the database to return approximate results in a very short time, and continue to improve their accuracy as more time is spent. Working on datasets of up to 100 gigabytes (and potentially larger), their "Wander Join" algorithm has achieved better sampling through random walks, returning results with the same accuracy (for example, 95% confidence and 1% error) in one-hundredth of the time compared with prior solutions using the same hardware.

> "In the early days, proving a conjecture and having a theorem with my name on it was my dream. Now seeing my algorithm used in practice is more satisfying"

PROF KE YI
Associate Professor of Computer Science and Engineering

Random walk is a technique that has been used to solve problems in many fields. Google's successful search engine is based on this idea, enabling it to prioritize the most authoritative pages related to the keywords being searched with a high degree of accuracy out of millions of web pages. In Prof Yi's research, this theoretical idea is successfully applied for the first time to the completely different scenario involved in approximate query processing. In addition, the algorithm has been integrated into an open source database to demonstrate its viability in the real world and not just in academia, bringing the sought-after goal of interactive data analysis a step closer.

Assisting such original insight is Prof Yi's unusual status as a member of both theoretical computer science and database faculty groups at HKUST, allowing him to bring knowledge from the two areas together to address practical problems. International recognition for the work of Prof Yi and his team includes winning the 2015 ACM SIGMOD Best Demonstration Award and receiving the 2016 ACM SIGMOD Best Paper Award. The work was carried out in collaboration with the University of Utah.

Making Data Centers Communicate Faster

Enter a single web search query and it can set in motion communication between thousands of physical machines in a data center as the machines quickly retrieve and collect the information corresponding to your keywords. A major goal of Prof Kai Chen and his research group is to accelerate such communication (data flow) between machines to help deliver the cloud and big data applications that now facilitate our way of life, including search engines, financial services, social networking, and many others.

Prof Chen's testbed implemented at HKUST.

Like Prof Ke Yi's work on databases, Prof Chen's approach to networked system design is theoretically significant and also practical. He seeks to achieve very high throughput and low latency (faster speed at the millisecond/microsecond level) while not requiring industry to make hard-to-adopt changes to applications or customize hardware. He is proving successful. In 2016, his team became the first in Hong Kong to have first-author papers accepted for the eminent ACM SIGCOMM conference. In these two papers, Prof Chen's group designed two systems, KARUNA and CODA, that answered key problems through innovative solutions that could be directly implemented.

KARUNA optimizes cloud application performance by delivering the first mix-flow (data flows with and without deadlines) scheduling solution for data centers. Unlike existing solutions, KARUNA maximizes the deadline meet rate of data flows with deadlines while minimizing the transmission time of data flows without deadlines. This is achieved by prioritizing deadline flows while controlling their sending rates, using the remaining bandwidth to schedule non-deadline flows. The system does not require prior knowledge of data size or impractical switch hardware modifications, filling an important gap in data center flow scheduling.

CODA is a system that can automatically identify and schedule coflows (a collection of parallel flows sharing a common performance goal) without requiring changes to applications – an impractical requirement of other coflow-based solutions. This is achieved by employing a machine learning algorithm to rapidly identify coflows, complemented by a coflow scheduler which is tolerant of identification errors. Testbed and large-scale simulations showed CODA's performance to be equivalent to solutions requiring applications to be adapted.

> "Data centers provide the infrastructure for big data and cloud computing. Our goal is to make data center communication faster"

PROF KAI CHEN
Associate Professor of Computer Science and Engineering

Prof Chen has also worked closely with major companies. Collaborations with Huawei have led to technologies for Software Defined Networks (SDN), prototypes that use machine learning for efficient communication, and patents. Prof Chen received Huawei's inaugural Distinguished Collaborator Award in 2016. At Tencent, the HKUST team has contributed to new-generation machine learning system Angel by designing an efficient data flow scheduling scheme that can improve the machine learning algorithm convergence time by up to 90%. The overall performance of Angel is 70 times faster than previous systems tested. Tencent has deployed it to support advertisement and video recommendation services.

Making these advances possible is the 100-plus machine data center that Prof Chen and his team have built from scratch, providing an essential in-house testbed at HKUST to try out the feasibility of a proposed solution. Once outcomes reach the required performance levels, large-scale simulations can be used to demonstrate scalability. Meanwhile, Prof Chen is setting his sights on further frontier work, including optical networking and artificial intelligence(AI)-enabled networking, currently undergoing testing at HKUST.

WHO'S WHO IN THE ARTS

Cutting-edge mathematical forensics at HKUST is bringing quantitative insights to art and literature

Two pictures, both thought to be the work of Raphael. How can mathematics help to ascertain if they really are by the famous painter? This intriguing area is among the domains of Prof Yang Wang, a specialist in mathematical forensics and stylometry, namely quantitative analysis of artistic or literary style.

To ascertain whether a specific painter or author created a work, he and his team are using the combined reach of machine learning and randomization theory to add to traditional methods of authentication, such as observational expertise and connoisseurship. For example, in visual art analysis, brush stroke measurements, texture models, fractal models, and color palette can be compared with other works by the same painter. In literary stylometry, average length of sentences, synonym pairs, and frequency of words, among other features, can be analyzed.

"The computing power for what we do was available 15 years ago, but people simply didn't think about doing such analysis," Prof Wang said. "What has made the difference is the increasing sophistication of techniques in statistical analysis, pattern recognition, signal processing, and machine learning that have opened the way for almost everything to be looked at from the perspective of big data and data analytics."

Prof Wang first became interested in stylometry in 2009 when the Metropolitan Museum of Art in the US asked him and a collaborator to examine a corpus of drawings by the great Flemish artist Pieter Bruegel the Elder (1525-1569) and famous imitations to see whether mathematical techniques could provide insight into identifying forgeries. Prof Wang's team later published their results in the international journal, *IEEE Transactions of Pattern Recognition and Machine Intelligence*. Since joining HKUST in 2014, he has helped his team members to develop more novel mathematical techniques in stylometry. These include a new randomization technique to analyze challenging open cases in authorship authentication, where the authorship in question is not limited to a small group of "suspects".

His team's research has been published in or submitted to peer-reviewed journals, such as *Applied and Computational Harmonic Analysis*, *Adaptive Data Analysis*, and *Signal Processing*.

In addition, Prof Wang sees great possibilities for mathematics to extend from arts and culture into other areas in social science and humanities in the future. "We have been looking at authorship stylometry but such work could easily move into other areas, such as computational rhetoric, sentiment analysis, text mining, image classification, even government surveillance and fingerprint analysis. We view this as an interdisciplinary area with far-reaching impact down the road."

> "I'm not an artist or historian, but this interplay of mathematics being applied to areas where few thought it could be applied is really exciting"

PROF YANG WANG
Chair Professor of Mathematics, Dean of Science

Is This a Raphael?

A drawing purported to be a Raphael.

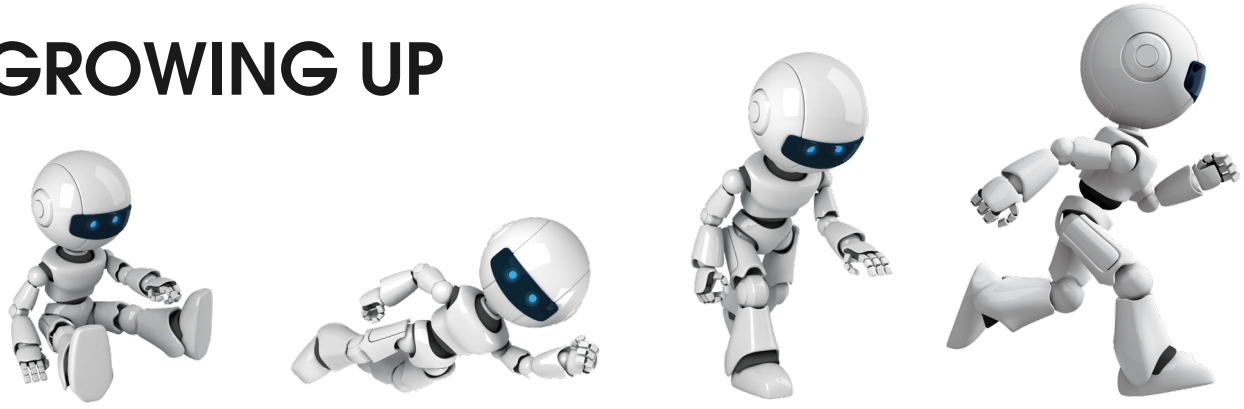
The drawing above is part of a private collection. Was it drawn by Raphael? To conduct stylometric analysis, HKUST researchers first extracted quantitative features from the drawing using wavelet decomposition and scattering transform. Similar features were extracted from a number of drawings known to be genuine Raphael works or forgeries provided by the collector. Features were then compared. Although such analysis does not draw definitive conclusions, their results showed that the drawing's style was consistent with a Raphael. The collector also provided some drawings of unknown provenance that bore a strong resemblance to those by Raphael. HKUST researchers showed stylistically they were inconsistent with Raphael.

Two works already established to be by the famous painter.

HUMANIZING ROBOTS

HKUST engineers are at the forefront of building machines that can learn, act, and sense emotions like their human creators, with far-reaching applications for the future. Such exploration into human-robot interaction is a key research focus at the HKUST Robotics Institute

GROWING UP



Like a baby, a robot learns to predict the consequences of its movement and adapt to the environment through repeated failure and trying again.

Robots now coming into being in HKUST labs are like babies. A child initially knows nothing of the world. But using its five senses – hearing, sight, touch, taste, and smell – an infant has the capacity to rapidly learn from what it perceives in the immediate environment and how that environment changes in response to its actions.

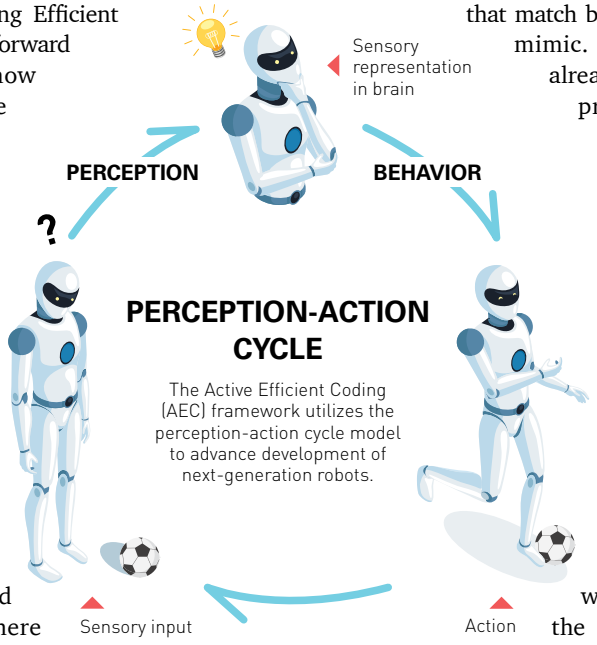
This is the perception-action cycle, understanding that is also vital for the development of the next generation of robots. The new robot may start its existence as a blank slate. But if, like a child, it has the capacity to teach and correct itself, it can do much more than a pre-programmed machine.

Prof Bertram Shi is leading research where electronics and computing meet biology and neuroscience. Prof Shi is renowned in the robotics community for his work in developing the Active Efficient Coding (AEC) framework for machine learning in collaboration with Prof Jochen Triesch's team at the Frankfurt Institute for Advanced Studies in Germany. This framework extends Horace Barlow's groundbreaking Efficient Coding hypothesis, put forward in 1961 to explain how the brain works at the neuronal level.

The brain, Barlow hypothesized, tries to form an efficient representation of the environment by switching on as few neurons as possible, thus minimizing the energy involved. Prof Shi and his team realized this hypothesis was incomplete, as it assumed a passive organism, where the properties of neurons adapt to the statistics of sensory input. What was missing from Efficient Coding was that organisms actively shape and optimize such statistics through their behavior. The researchers added the effect of active behavior to the hypothesis in work first presented at the 2012 IEEE International Conference on Development and Learning and Epigenetic Robotics.

The team's AEC framework takes into account how animals and humans utilize their motor system to facilitate the efficient encoding of relevant sensory signals. An example is the simultaneous movement of both eyes in opposite directions to align the images from the left and right eyes so that they can be fused into a coherent percept, also known as a "vergence eye movement". The framework is a powerful unifying principle for the development of neurally inspired and driven robots. It underpins technology that will enable robots to become more adaptive, structure their own behavior automatically, and predict interventions that match biological systems they mimic. Prof Shi's team has already shown this single principle can account for the emergence of a wide range of other behaviors, such as visual tracking and accommodation (focusing), and the automatic combination of multiple sensory cues.

Prof Shi explained: "In developmental robotics, ideally we want to put a robot in the environment and let



PERCEPTION-ACTION CYCLE

The Active Efficient Coding (AEC) framework utilizes the perception-action cycle model to advance development of next-generation robots.

it structure its own interactions. It has to learn from its interactions, like a baby. We then have something that is adaptive."

By combining the latest advances in unsupervised machine learning and reinforcement learning, the team formulated a mathematical model for the simultaneous development of perception and action that encapsulated a simple idea. Perception develops in order to enable an organism to understand the environment based on the input from its sensory organs. Behavior develops to stabilize the sensory input to simplify the process of understanding the environment.

The focus for their application of AEC is the visual system, which is vital for the more autonomous machines of the future if they are not only to "see" but can also respond to what they "see". For the robot, this involves creating a sight system that can track and follow an object and then stabilize the image of the object captured by video camera to make it easier to understand. It then creates an internal representation of the environmental state. The team is experimenting with robots that can control the angle incline of the eyes, moving their position as an object comes closer, and with an arm programmed to move to that location.

The system continuously recalibrates itself, learning by failing and trying again – a process that Prof Shi also describes as "babbling", like a baby babbles as it learns to talk. This process happens dynamically whenever the system is operating, just as learning is always active in biological organisms. In another breakthrough, the team has demonstrated that the system exhibits another important biological capability: self-repair. Using the framework, a robot, if injured, can automatically readapt itself.

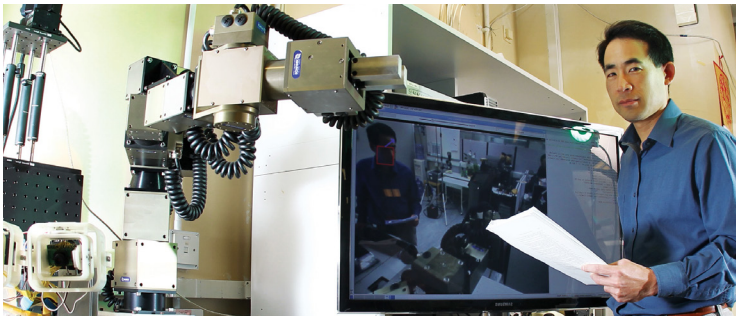
While the HKUST researchers are now refining this technology, Prof Shi is confident that it will not be long before the eye movement system is ready for application outside the laboratory, for medical, consumer, and industrial uses. He expects this capability to be built into robots used in industrial settings to support greater automation in manufacturing processes that require more human-robot interaction – where the human understands the robot, and vice versa.

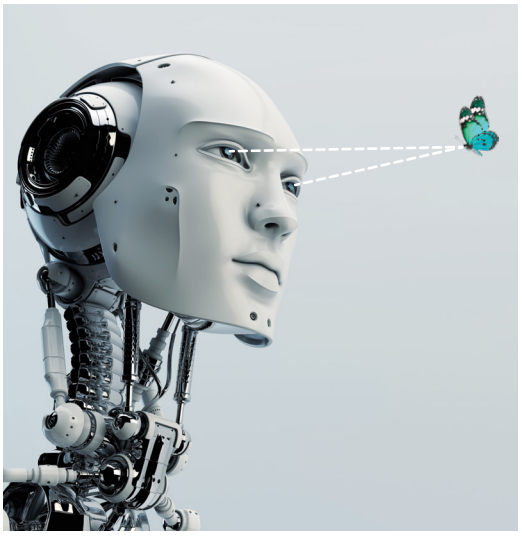
Medical applications for systems using the AEC framework are also being developed. For example, Prof Shi's collaborators in Germany are now working to apply the principle to the development of virtual reality training systems to improve sensorimotor coordination in patients with eye movement disorders. "Robots that mimic the brain's ability to adapt might one day be able to help the biological system when things go awry," said Prof Shi.

Prof Shi's team comprises a group of multidisciplinary talents who are at the core of its success. "They need strong math skills to understand the algorithms, and coding skills, and a focus informed by engineering, neural science, and physics, as well as creativity and imagination," he said.

> "From human biology we can draw much to inspire our understanding of the development of robotics"

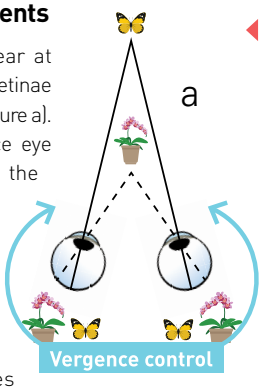
PROF BERTRAM SHI
Professor and Head, Department of Electronic and Computer Engineering





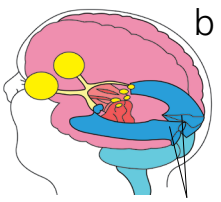
Vergence Eye Movements

Objects in the world appear at different points in the two retinae depending on their depth (Figure a). Humans perform vergence eye movements, which adjust the angle between the two eyes, to align the images on the two retinae so that they can be fused into one coherent percept. Generating the correct control signals requires information from the two eyes to be combined (Figure b). Human babies normally learn how to do this four months after birth. The Active Efficient Coding (AEC) provides an account for how this behavior emerges.



Objects at different depths appear at different points in the retinae of the two eyes.

In humans, visual information from the two eyes is routed separately to an area of the brain in the back of the head known as the primary visual cortex, where information from the two eyes is combined.



Primary visual cortex

I KNOW HOW YOU FEEL

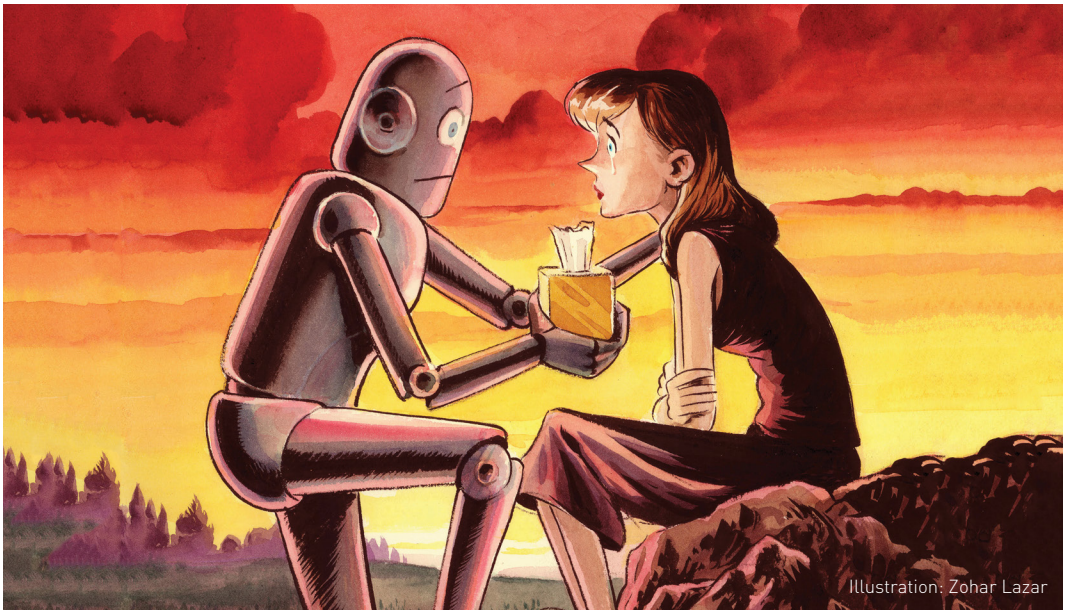


Illustration: Zohar Lazar

It is perhaps no coincidence that it has taken a woman engineer to build the virtual mind of a robot that goes further than any other in the empathy it – or rather she – can display.

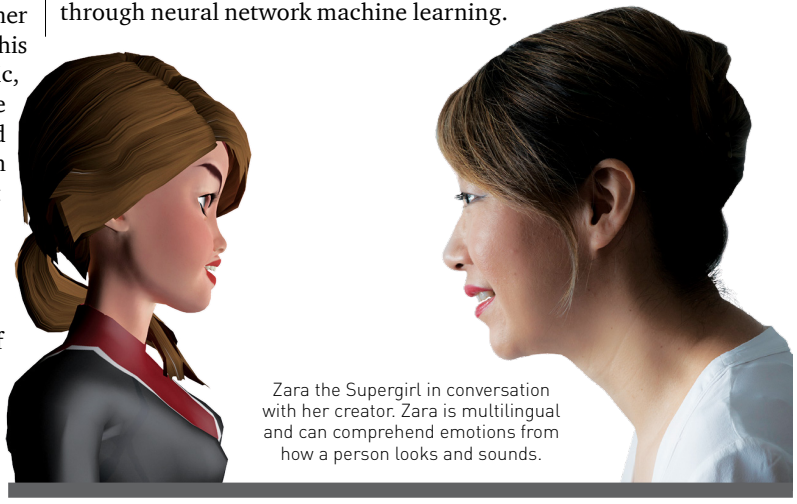
Meet Zara the Supergirl, the virtual agent with emotional intelligence created at HKUST by one of the leading researchers in the field, Prof Pascale Fung, and her diverse student team.

Unlike most of the current speech recognition systems, Zara has been programmed to detect meaning and intent during conversations and respond to the emotion and personality type of her user by observing their facial expression, manner of speaking, language used, and the context. This breakthrough has attracted global academic, industry and popular media attention since Zara was first unveiled at the 2015 World Economic Forum in Davos. While some form of emotional intelligence in avatars is not new, Zara represents the first full integration of multimodal emotional perception and response in an artificial intelligence (AI) system.

The frontier development is a result of advanced tools and algorithms devised by Prof Fung, whose goal is to create virtual agents and robots that can be viewed as buddies rather than unfeeling machines. What makes Zara's extraordinary "mind" tick? "We came up with an empathy module for recognizing emotion from the way people talk, based on large amounts of audio data from different nationalities and cultures," Prof Fung said. This required teaching machines not only to recognize the meaning of words but also comprehend acoustic signals and facial expressions – just as a human would. "And by learning, Zara can figure out what to do next. She uses recognition of emotion and personality to enable the system to converse and feel what the user feels."

Such advanced functionality builds on the University's expertise in multilingual spoken language understanding developed over the past two decades. Zara's "talents" are achieved through neural network machine learning.

> "The concept of empathetic robots can go far. In the next few years you are going to see an explosion of ideas"
>
> **PROF PASCALE FUNG**
> Professor of Electronic and Computer Engineering



Zara the Supergirl in conversation with her creator. Zara is multilingual and can comprehend emotions from how a person looks and sounds.

Zara the Supergirl

Prof Pascale Fung

The learned output is derived from "neurons" firing signals across multiple layers while simultaneously adjusting weighting functions and biases across these layers. Algorithms developed by the HKUST team enable them to make Zara and related applications increasingly responsive in real time.

The personality recognition capacity that Prof Fung's team has developed draws on common classifications used by psychologists, including the Big Five personality traits and Myers-Briggs indicators. Personality of the user is assessed in a question-and-answer session that takes less than five minutes. Zara's responses mimic how we intuitively react with different audiences, whether a child or adult, man or woman.

Since Davos, the team has refined multiple facets of linguistic and emotional intelligence for robots and avatars. As Zara interacts with more people and gathers more data, the machine-learning algorithms enable her to be more intelligent and more empathetic. The technology behind Zara will take the leap from screen to embodiment in the form of a receptionist robot, who will interact with visitors to HKUST, and guide them to their destinations.

The potential applications of empathetic machines are endless. Prof Fung is particularly excited about uses in healthcare, which range from monitoring when an elderly person needs help to assisting in the diagnosis of Alzheimer's disease. Prof Fung's team has also developed a virtual psychologist using similar technology to Zara, focusing on detecting stress and depression in a user, and providing counseling services. In human resources, it can be used for initial job interviews without the unconscious bias inherent in human interviewers. For business and finance, the team is extending speech and language data analytics to sentiment analysis.

The technology is already available commercially in a smart "robot speaker with a heart" that senses your mood by interacting with you, and responds with the music and lighting to match. Music is suggested according to the time, weather, and the user's previous listening choices. The classification of music is again based on a neural network algorithm that recognizes the mood, genre and even artist for each piece.

Prof Fung, a founding member of the Human Language Technology Center at HKUST, established in 1997, leads an international team of postdoctoral researchers and students from Asia and Europe. This is helpful for the research as students coming from different cultural and educational backgrounds bring different insights and perspectives to the interdisciplinary field of AI. The team is enhancing AI capacities in areas such as conversational humor, abusive language recognition, mood recognition, music retrieval, and sentiment analysis. One of her students is working on the algorithms that will make the voice of virtual agents such as Zara more emotional.

Prof Fung and her team of students from diverse backgrounds work to enhance the emotional intelligence of their virtual agents.

While Prof Fung is fascinated with humanistic robots, she is alert to the potential societal challenges that AI poses. She is a member of the Global Future Council on AI and Robotics of the World Economic Forum, which advises policymakers and CEOs to be mindful about the usages of technology, and believes laws and regulations will be needed to prevent abuse.

Empathetic Robots, Wide-reaching Applications

FROM LAB TO REAL LIFE

Meet some of the HKUST researchers whose innovations are moving to market

(Left to right) front row: Prof Shengwang Du, Prof Richard So, Prof Ying Chau. Back row: Dr Langston Suen, Dr Yu Yu, Mr Calvin Zhang, Dr Teng Zhao.

HKUST has set up a supportive infrastructure for research breakthroughs to make the transition from idea to market and on to improving people's lives. This infrastructure includes entrepreneurship programs, funding, and knowledge transfer systems and processes offered through the Technology Transfer Center, Entrepreneurship Center, and HKUST R and D Corporation Ltd. The University also leverages funding opportunities provided by the Hong Kong government through the Technology Start-up Support Scheme for Universities (TSSSU) under the Innovation and Technology Fund. HKUST has incubated more than 90 technology-based start-up companies, many born from joint research efforts between faculty members and their students. It has licensed hundreds more research discoveries to industry partners. Here, three HKUST research teams, who are helping the world see and hear better, showcase the innovations that have led to spin-off companies.

VISIBLE DIFFERENCE

People with diseases that require frequent injections into their eyeballs have been given hope that the ocular medicines they need can be delivered without pain and much less frequently.

Prof Ying Chau leads research in biomaterials for drug delivery, specializing in the ocular area. Her research teams have come up with two breakthroughs for delivering ophthalmic drugs to the eye, which they hope will improve the treatment of increasingly common diseases such as age-related macular degeneration and diabetic retinopathy. Both have now been patented through the University's Technology Transfer Center, in preparation for downstream start-up development, led by the students involved in the initial studies.

The first invention has been pioneered by Prof Chau's team since 2006 and is now being championed by Dr Langston Suen, who was trained in her lab. This uses ultrasound to non-invasively deliver drugs to the back of the eye to treat retinal diseases, replacing injections into the eyeball that are often painful, leave wounds, and come with the risk of infection, among other side effects. Ultrasound, the team discovered, provides physical energy that temporarily disrupts natural ocular barriers, opening the door for drug treatment. The innovation won the Institution of Engineering and Technology Healthcare Technologies Innovation Award in the UK in 2016, among other prizes, and is now poised to compete in a global drugs market worth nearly US$10 billion for the treatment of retinal diseases according to the Controlled Release Society, a premier organization worldwide for delivery science and technology.

The second breakthrough, derived from studies led by Dr Yu Yu, a postdoctoral research fellow in Prof Chau's team, employs a new injectable hydrogel biomaterial. The ocular drug is wrapped in the gel to allow its slow release, thus extending the time between treatments for eye diseases to at least six months, compared with monthly injection required by traditional treatment.

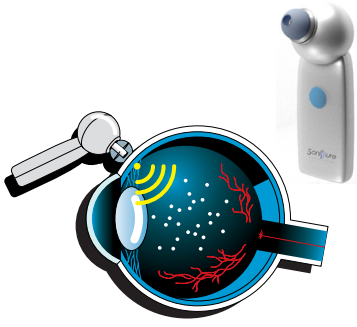
The hydrogel makes use of natural hyaluronic acid (HA), which is similar to the vitreous, a gel found in the eye, with additional properties engineered to control the speed of degradation. "We started with HA and modified it to become an injectable gel. The chemistry and formulation are focused on extremely slow release," said Prof Chau.

The hydrogel has excellent compatibility with the eye based on preclinical testing. It can also improve treatment of front-of-eye problems, such as dry eye and cornea wounds, and can be applicable for human and veterinary use. Its use for treating dry eye in dogs is already being evaluated together with a local veterinary hospital.


Age-related macular degeneration

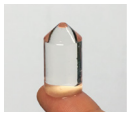

Diabetic retinopathy

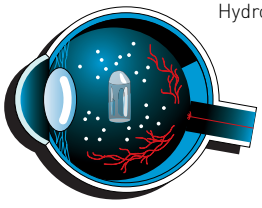
Non-invasive ultrasound technology



An ultrasound applicator with low frequency range enhances the transport of macromolecules across the sclera (tough white part of the eye), thus allowing the ocular drug to permeate into the eye.

Drug-loaded hydrogel biomaterial


Hydrogel



A novel hydrogel-based drug carrier can maintain the drug's therapeutic effect in the eye for a long period of time, reducing the need for regular treatment by injection.

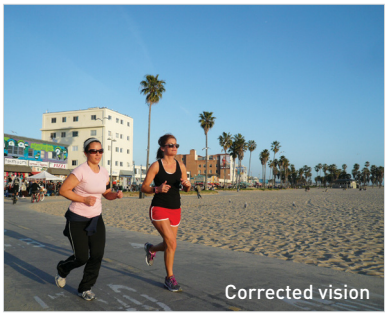
Dr Yu Yu (left) and Dr Langston Suen (right) with their mentor Prof Ying Chau.

> “As eye diseases become more prevalent in the elderly, our versatile technologies can be tailored to address delivery challenges of emerging therapeutics as well as teach ‘old’ drugs new tricks”

PROF YING CHAU
Associate Professor of Chemical and Biological Engineering

The next step is to test the efficacy and safety of both the ultrasound and hydrogel technologies before their use can be extended to people.

The technology involved has been licensed to two companies – Sonikure Technology Limited to commercialize the ultrasound innovation, and Pleryon Therapeutics Limited for the hydrogel biomaterial. Dr Suen and Dr Yu are the respective founders of the two companies. Prof Chau has worked closely with them since she nurtured their interest in research as undergraduates.



On-the-ground inSIGHT **into Health Solutions**

Prof Ying Chau has extended her transfer technology insights and passion for helping people through initiating the Student Innovation for Global Health Technology (SIGHT) program, which fosters undergraduates’ application of knowledge and innovation in solving global health problems.

Projects include assisting patients suffering from muscular diseases to input text with a customized keyboard in Hong Kong, tackling water problems using natural plant moringa for home water purification in Guizhou, Mainland China, introducing the use of portable camera technology to screen for diabetic eye diseases in Indonesia, and developing an electronic medical record system for mobile clinics serving slum residents in Cambodia. The latter project won first prize in the 2016 Rice 360° Global Health Technologies Design Competition in the US.

Students are given the opportunity to observe problems firsthand and embrace empathy in the design-thinking process. Interdisciplinary teams are charged with creating and prototyping workable, open source solutions that address real-life problems under resource-limited settings. “This is a holistic way for students to learn, and of approaching knowledge transfer and technology penetration into the community,” she said.

SIGHT runs credit and non-credit courses and activities, overseas study trips, and a Scholar Program providing funding for students to spend one or two months in the field.

HKUST students developed EasyMed, an innovative electronic health record system for mobile clinics, which was successfully launched in Cambodia in 2016.

BREAKING THE SOUND BARRIER

For the millions of people around the world who suffer from hearing loss, sound can be restored through a revolutionary audio technology delivered through a smart phone at a fraction of the price of traditional hearing aids, thanks to knowledge being transferred from HKUST research.

The technology is underpinned by Prof So's long-established research on audio perceptions in noise and binaural hearing, as well as computational ergonomics for enhancing the human experience in sight and sound.

Statistics indicate that the application of such research could help many people.

Conventional hearing aids (left) amplify both targeted and background speech while HKUST's noise-separation technology (right) allows hearing aid users to focus on audio signals they want to hear.

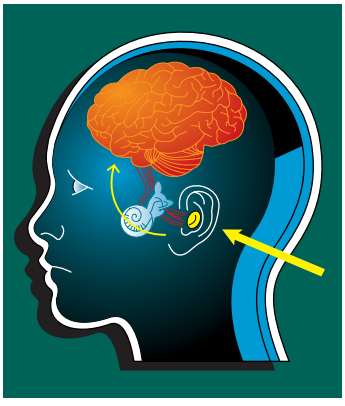
Prof Richard So and his MPhil student, Calvin Zhang, have come up with a new way of separating target signals – for example, speech – from irritating background noise, enhancing clarity in difficult listening environments. In comparison, conventional hearing aids, lacking the noise separation function, convert sound waves into digital signals and amplify all of them before feeding them back into the ear.

The HKUST advance is built on an algorithmic framework, combining pattern recognition and binaural directional sound technology. In a similar way to the brain's ability to cope with even tiny differences in sound, the algorithms capture and label audio signals according to their acoustical attributes, including frequency, tempo and amplitude. Targeted signals are effectively separated from other undesired signals. In practice, users can select and amplify the sound they want to hear to the optimal frequency or intensity.

In China alone there are an estimated 72 million people with severe or moderate hearing impairment, of whom 92% are not using any form of hearing aids, according to a 2015 survey by the China Rehabilitation Center for Hearing and Speech Impairment.

With the assistance of HKUST's Technology Transfer Center and Entrepreneurship Center, the patented technology has now been licensed to Incus Company Limited, founded by Prof So and Calvin.

One novel aspect of the commercialization of the technology involves an innovative mobile app, which allows users to test their hearing online, then download the customized software that will manage the sound they hear through their own earphones or customized blue-tooth earphones.

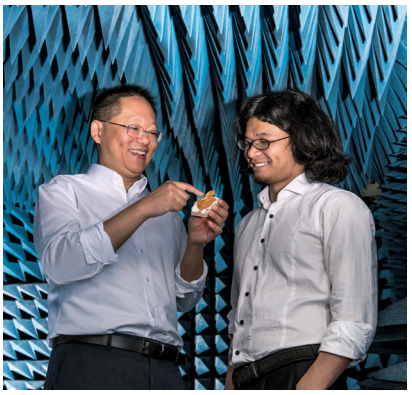


HKUST's customized hearing aid allows users to manage the sound they hear.

A next step is to develop a state-of-the-art behind-the-ear model. "The challenge now is to miniaturize the technology to a portable size," said Prof So. Incus has plans to collaborate with a Hong Kong manufacturer specializing in medical equipment. Prototypes are being developed for submission to both the US and China Food and Drug Administrations.

Prof So is confident Incus can reduce the price for a hearing device significantly, possibly by as much as 90%, through the mobile app approach.

Incus won first prize in the start-up category of the "New World Cup" First Qianhai Shenzhen-Hong Kong Youth Innovation and Entrepreneurship Competition, while Calvin received first prize in the Cross-strait, Hong Kong and Macao Innovation and Entrepreneurship Competition.



Prof Richard So (left) with his student Calvin Zhang.

> "Our uniqueness is in our algorithms that mimic the brain's capability to pick up and handle multiple sounds"

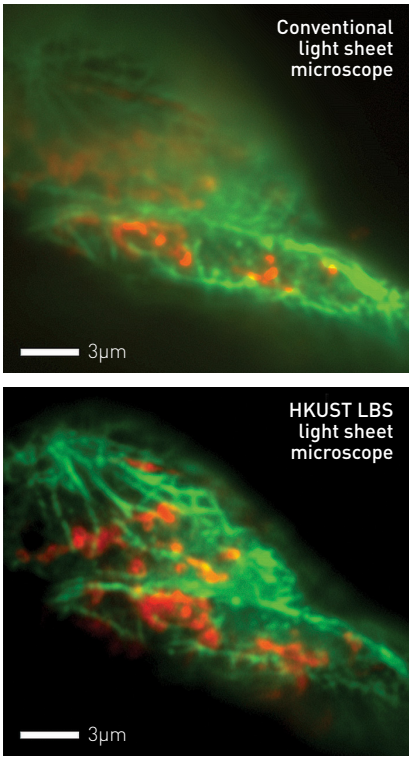
PROF RICHARD SO

Professor of Industrial Engineering and Logistics Management

LIFE UNDER THE MICROSCOPE

Creative interdisciplinary collaboration between physicists, biologists, and chemists has enabled HKUST researchers to develop new-generation bioimaging innovations in super-resolution and light sheet microscopy. The leading-edge work has put Hong Kong on the map as a center for such technology and is being made available beyond the University through two start-up companies led by physicist Prof Shengwang Du.

The initial microscopy project was started by Professor Emeritus Michael Loy, then Acting Head of the Division of Life Science. Prof Loy saw the gap in microscope technology and brought together a group of physicists and life scientists to develop the University's own super-resolution microscope. This created an interactive ecosystem whereby the physicists used their knowledge of atomic, molecular and optical physics to assist the life scientists in their investigations of tiny structures in cells and tissues.



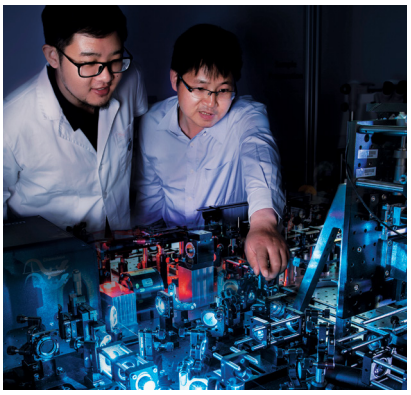
HKUST Line Bessel Sheet (LBS) light sheet microcsope providing high resolution images, with improved optical sectioning and signal-to-noise ratio at the cellular level, compared with a conventional light sheet microscope.

The result was state-of-the-art super-resolution localization fluorescence microscopes, which have advanced HKUST life scientists' capability to gain fresh insights on topics ranging from the fine details of mitochondrial function to vesicle dynamics to protein co-localization (see also *Research@HKUST* 2016).

Three technological breakthroughs developed by Prof Du, Prof Loy and then PhD student Teng Zhao assisted HKUST in creating their first super-resolution microscope: stabilizing the smallest vibrations, even from air-conditioning, through "active locking" to capture images to 20 nanometers, thus increasing image accuracy and precision by 10-fold compared with conventional equipment; increasing the speed of image acquisition and simultaneously providing multiple colors in a single sample, thus enabling life scientists to distinguish between the tiniest molecules and cellular components; and offering user-friendly ways to optimize the protocol for biological sample preparation, increasing accessibility to a wide range of microscopic applications.

More than 10 research groups at HKUST are now using this cutting-edge technology, with the physicists constantly adding new features to enhance either the capabilities of the system or the user-friendliness of its interface. These efforts are undertaken at the University's Super-Resolution Imaging Center.

Following the success of this microscope, the team went on to develop high-resolution light sheet microscopy technology which can reduce light exposure by 1,000 times compared with conventional microscopes. This significantly reduces phototoxic damage to cells, thus enabling imaging of live cells. In addition, the HKUST model produces 5D images with the additional dimensions of time and color, while conventional confocal microscopes can only produce 3D images.



Prof Shengwang Du (right) with his student Dr Teng Zhao.

> "Our light sheet technology enables scientists to take images of even the most light-sensitive specimen in greater detail and without killing the cells"

PROF SHENGWANG DU
Professor of Physics

Both microscopy projects received funding from the Hong Kong Research Grants Council as well as the University.

Patented super-resolution microscopy technology has been licensed to spin-off company NanoBioImaging Limited, co-founded by Prof Du in 2013. As there are few other tools with a similar level of sophistication readily available in Greater China, the HKUST technology is being used by other universities in Hong Kong, Mainland China and Taiwan, and the company is ready to expand to the global market. A second spin-off company, Light Innovation Technology Limited, was launched in 2016 to commercialize the light sheet advances. Its first product has been released for demonstration. Both companies have received start-up funding support from the Hong Kong government.

DEMYSTIFYING CHINA'S FINANCE

HKUST economists and social scientists have built up a concentration of research, providing original understanding on China's emergence as a global economy for academic, policy and business leaders East and West. In this issue, the focus is on the capital flows and asset bubbles, informal financing and shadow banking, that have accompanied China's stunning economic growth

> “Analyses are difficult if we assume people are irrational because irrationality has limited use in making predictions”

PROF PENGFEI WANG
Professor of Economics

INS AND OUTS OF CAPITAL FLOWS AND ASSET BUBBLES

The emergence of China as a major source of capital for developed countries is a phenomenon that has caught economists and politcal leaders by surprise. Research at HKUST offers novel perspectives on the flows of capital in and out of China and its massive trade imbalance with the West, with economist Prof Pengfei Wang and his collaborators becoming the first to quantify this data and use it to develop a new theory to explain the dynamics involved.

Classic economic theory has long suggested that capital normally flows from developed countries, where it is abundant, to the developing. However, economists have been perplexed as to why the reverse now appears to be true. This is particularly the case for China, which by the end of March 2017 was holding US$3 trillion in foreign reserves, mostly US government bonds.

Prof Wang explained that this is an outcome of China’s immature financial system. Due to the underdeveloped banking-credit-financial system, households have limited investment options. At the same time, households and firms have borrowing constraints. This gap creates financial frictions: households save excessively to self-insure against unpredictable shocks. However, their huge financial capital cannot be effectively channeled to firms.

Prof Wang observed that financial capital in China yields a lower rate of return compared with the US. This drives domestic household savings to flow to the US for higher returns, despite government-imposed currency restrictions, and the rise of informal financing platforms. He also noted that

Prof Wang's work shows how China's underdeveloped financial system explains the capital flows in and out of China and its massive trade imbalance with the West.

50% of GDP

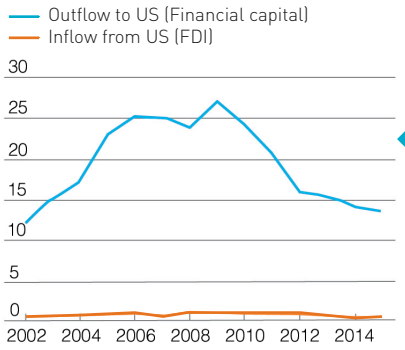
China's total accumulated net **financial capital outflows** to developed countries in 2010

capital is flowing from the US to China in the form of Foreign Direct Investment (FDI), which involves the investment in a firm's machinery and equipment. This is because China has a higher rate of return on fixed capital than the US – consistently over 20% in recent decades.

"Many countries accuse China of manipulating its exchange rate by keeping it artificially low to generate a huge current account surplus," said Prof Wang, whose findings, published in *The Economic Journal* (2015), dismiss currently popular political views. "We argued this was not the case. First, it is the real exchange rate, and not the nominal exchange rate, that determines the current account balance. While China may adjust its nominal exchange rate, the real exchange rate is determined by economic forces and not by government intervention. Second, current account surplus also exists in many other emerging countries with a flexible exchange rate, so it suggests that an account surplus is caused by other reasons. Third, we showed that financial frictions can quantitatively explain a large current account surplus in our model.

"Due to financial frictions, China is lending money to the US at very low interest rates, for example through US Treasury Bonds. But the Chinese debt repayment is very high in foreign direct investment." Since FDI earns a much higher rate of return than bonds, China always receives negative net income payments. Thus, the country needs to export more than it imports, namely run a current surplus, to finance negative net income payments.

Capital flows (China vs US), % of China's GDP



The orange line shows the accumulated net FDI outflows from the US to China as a percentage share of China's GDP; the blue line shows the accumulated net financial capital outflows from China to the US as a percentage share of China's GDP.

Prof Wang's theory suggests that, in the long run, if China can improve its banking-credit-financial system, household savings can be channeled more effectively to its domestic production sector. In addition, the greater availability of credit for private enterprise would allow the sector to expand, reducing the role of FDI in production investment. It could also assist in reducing the liquidity that has helped fuel China's housing bubble.

This builds on Prof Wang's earlier work on asset bubbles, published in the *American Economic Review* (2012) and *Econometrica* (2013). Asset bubbles, defined as the difference between fundamental value and market value, had previously only been studied on the periphery of economics due to the common assumption that they are driven by irrational behavior that does not lend itself to predictions and economic modeling. Prof Wang challenged this outlook, theorizing that asset bubbles are in fact driven by sentiments of optimism and pessimism rather than irrationality.

20% of GDP

Accumulated net **FDI inflows** received by China from developed countries in 2010

He and collaborator Prof Jianjun Miao at Boston University developed a new method to detect asset bubbles, using a structured model in which asset prices are derived from people's optimistic view and linked to real variables, including stock prices and investment in the economy. They used US stock prices from 1985 to 2012 as the starting point. The period covered the bursting of two major bubbles: the internet bust of 2001, and the US housing collapse of 2007. A basket of economic data was analyzed, including stock prices, consumption, investment, hours worked, and the relative price of investment goods.

Prof Wang has also used his theory to analyze the housing bubble in China and the effectiveness of policy to dampen it. This includes assessing the unintended consequences of moves to increase stamp duty and limit purchases to local residents.

"Credit-driven bubbles are very fragile because optimistic belief can turn to pessimism with a slight change in the fundamentals. Asset prices drop, credit gets crunched, lending and liquidity evaporate, and investment and consumption fall," said Prof Wang.

His research has led him to believe that if the bubble bursts in China, the consequences could be more severe than the collapse of the US housing market in 2007-08, making HKUST economists' work in monitoring China's emergence all the more important.

INFORMAL LENDING POWER

Since the start of economic reform in the late 1970s, China's economy has grown exponentially despite an initial lack of private property rights, capitalism without democracy, and a private sector that has thrived without access to bank credit. Both quantitative and qualitative research by HKUST social scientists have helped to unravel those paradoxes through rigorous field studies in China that go beyond publicly available government statistics and reports.

Such research is challenging generalizations and misconceptions about China and providing fresh insights into the country's rise over the past 40 years. One key area is the less understood role of informal financing institutions and resources. This includes the role of a so-called "shadow banking" system that started out as a means to finance China's petty private sector, but has since expanded into all reaches of the Chinese economy, including local public finance, real estate development, and investment vehicles for the growing middle class.

Research conducted across the country by political scientist Prof Kellee Tsai has tracked how small and medium-sized enterprises (SMEs) could have risen so quickly to become the most dynamic element of the country's economy, despite their lack of access to bank credit lines. In 2010, state-owned enterprises under the State-owned Assets Supervision and Administrative Commission constituted 62% of GDP. However, by 2013, the private sector accounted for 60% of GDP even though the country's banks have traditionally confined the bulk of their lending to the state-owned sector. Over 99% of China's firms are SMEs, yet state-affiliated firms receive over 85% of loans extended by state-owned commercial banks, she has noted.

Prof Tsai, who joined HKUST from Johns Hopkins University in 2013, was one of the first academics to explore the scale and significance of China's world of informal finance. In her research stretching over 20 years,

> "My overarching agenda has been to identify alternative and more accurate ways of understanding what's really going on in China's political economy"

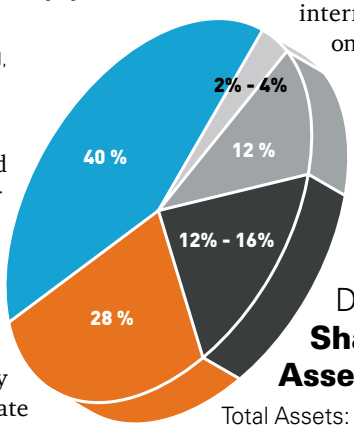
PROF KELLEE TSAI
Chair Professor and Head,
Division of Social Science

she has conducted interviews with over 900 entrepreneurs in 10 provinces and municipalities to understand how this has happened and written extensively about China's private entrepreneurship and financing.

Her books on China's political economy include *Back-Alley Banking: Private Entrepreneurs in China* (Cornell University Press 2002); *Capitalism Without Democracy: The Private Sector in Contemporary China* (Cornell University Press 2007); and, most recently, *State Capitalism, Institutional Adaptation, and the Chinese Miracle,* the latter co-edited with Prof Barry Naughton, UC San Diego (Cambridge University Press 2015).

Prof Tsai's extensive research has shown that China's informal finance is not necessarily legal or illegal. A variety of non-banking financing mechanisms has been able to develop within the complexity of China's bureaucratic system. If a credit facility is prohibited under banking regulations, another bureaucracy may have approved it.

She has categorized such non-banking financial intermediation by their degree of institutionalization. This ranges from casual borrowing among family and friends at the least institutionalized end of the spectrum, to registered non-banking financial institutions at the other. In the middle is a grey area of "semi-institutionalized practices" that are documented but unregulated. These include the rise of financial technology (FinTech) and online peer-to-peer platforms. Due to its unregulated character, internet finance is regarded as part of shadow banking in China, and new financial technologies have fueled shadow banking. By 2014, over 60% of the 675 million internet users in China had used online financing products.



Distribution of
Shadow Banking Assets (2012)
Total Assets: RMB 24-25 Trillion

- Shadow banking activities in Big Four banks: asset management, trusts, financial leasing
- Wealth management products in trusts & banks
- Informal finance: credit guarantee companies, pawnshops, investment companies
- Asset-backed securities, repos, & money market funds
- Other underground financing: private money houses, money brokers, business association financing, online services, etc.

Source: Wang, B.L. & Li, J.J. (2013). The size of Chinese shadow banking, risk assessment and supervision. *Journal of Central University of Finance & Economics*, 1(5), 20-25.

In addition, the concept of "shadow banking" takes a different form in the China context. While shadow banking has been broadly defined by the international Financial Stability Board as "the system of credit intermediation that involves entities and activities fully or partially outside the regular banking system, or non-bank credit intermediation", in China it also includes local government debt – involving fiscal authorities funding infrastructure development through lending to local governments – and money market funds and wealth management products issued by trust companies connected to state banks.

Prof Tsai observes that China's 2008 stimulus plan, launched in response to the global financial crisis, incentivized the rapid expansion of shadow banking among government entities. Shadow banking ranged from an estimated 26% to 69% of China's entire GDP by 2012, and nearly half involved off-balance sheet activities of official state banks. Activities included asset management and financial leasing while the extension of loans to real estate developers and private businesses through trust companies helped to fuel a real estate boom that some analysts regard as a "bubble".

Quick cash from Wenzhou's oldest pawnshop.


People shop from street vendors in Shanghai.

OVER 85%
of bank loans go to state-affiliated firms

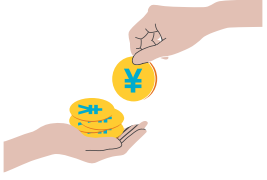
More recent work on shadow banking and SME finance has shown that not all shadow banking poses a risk to the banking system: "Some is badly needed to supply SME credit," she said. It makes sense to legalize informal financing selectively, and regulate it rather than drive the business underground. However, investors do need protection through appropriate regulation.

China defies conventional academic frameworks of political economy in other ways, Prof Tsai said. One of the most popular ideas in social science, "modernization theory", argues that when a country's GDP reaches a certain level, a transition to democracy will naturally follow. This is based on models such as England's experience following the Industrial Revolution, whereby capitalist development led to demands for political representation. If private entrepreneurs pay taxes, then they will want to have a say in politics, according to conventional thinking.

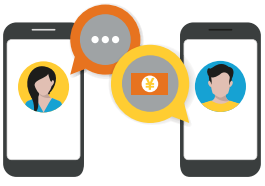
OVER 99%
of China's firms are SMEs

But China's entrepreneurs have had an impact on the political system despite the lack of suffrage, according to Prof Tsai's research. She pointed to major constitutional reforms legalizing private enterprise and property, and the toleration of informal lending institutions. "The state has embraced what is going on at grassroots level. It has been strategically responsive, which is one reason why China has managed to provide a hospitable climate for capitalist development without making a political transition to liberal democracy."

Forms of Non-banking Financial Intermediation



LEAST INSTITUTIONALIZED
- Interest-free uncollateralized lending among friends, family, and businesses
- Underground money lenders (with high interest)
- Trade credit among businesses



SEMI-INSTITUTIONALIZED
- Internet finance (since 2007)
  - Peer-to-peer (P2P) platforms
  - Crowdfunding
- Non-governmental investment alliances
- Rotating savings and credit associations
- Reciprocal loan guarantee networks

INSTITUTIONALIZED
- Microfinance/small loan companies and credit guarantee companies
- Leasing companies
- Trust and investment companies
- Mutual aid societies
- Pawnshops

FACTS AT A GLANCE

Established
October 1991

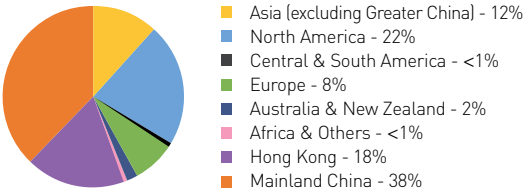
Academic Departments and Divisions
20

Faculty Members (Regular)
641 # ^

as at June 2017
^ includes teaching-track faculty

Faculty Profile

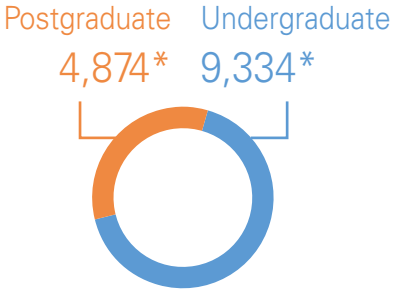
Academics come from 33 countries/regions.



Student Enrollment
14,208*

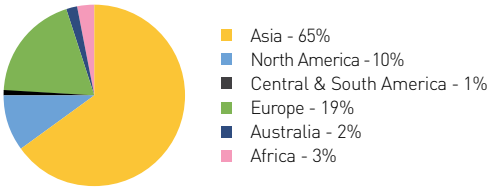
HKUST has the highest percentage of international students (8.4%) among all local universities.

* as at December 2016



International Postgraduate Students

Students come from 60 countries/regions.



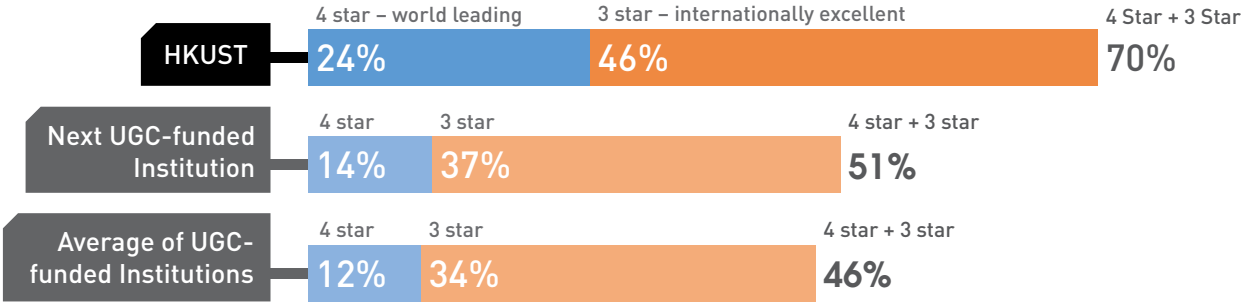
University Rankings+

+ as at October 2017

HKUST		
#2	World's Top 50 Universities Under 50 (four years in a row)	QS Top 50 Under 50 2014-2017
#3	World's Top 400 Asian Universities	QS Asian University Rankings 2018
#6	Asia's Top 300 Universities	Times Higher Education Asia University Rankings 2017
#13	World's Top 150 Universities	Emerging Global Employability University Ranking 2016
#30	World's Top 800 Universities	QS World University Rankings 2018
#44	World's Top 800 Universities	Times Higher Education World University Rankings 2018
School of Science		
#27	World's Top 500 Universities in Chemistry (No. 1 in Hong Kong)	QS World University Rankings by Subject 2017
#23	World's Top 300 Universities in Materials Science (No. 1 in Hong Kong)	QS World University Rankings by Subject 2017
School of Engineering		
#15	World's Top 400 Universities in Engineering and Technology (No. 1 in Hong Kong for 10 years in a row, 2007-2017)	QS World University Rankings 2017
#23	World's Top 400 Universities in Mechanical, Aeronautical and Manufacturing Engineering (No. 1 in Hong Kong)	QS World University Rankings by Subject 2017
#29	World's Top 400 Universities in Electrical and Electronic Engineering (No. 1 in Hong Kong)	QS World University Rankings by Subject 2017
School of Business and Management		
#1	Global EMBA Ranking – Kellogg-HKUST EMBA Program	Financial Times EMBA Rankings 2017
#26	Top 100 Business School Research Rankings (No.1 in Asia since the ranking was published)	University of Texas at Dallas (UTD) Business School Research Rankings 2017
#17	World's Top 200 Universities in Accounting and Finance (No. 1 in Asia)	QS World University Rankings by Subject 2017
#24	World's Top 400 Universities in Economics and Econometrics (No. 1 in Greater China)	QS World University Rankings by Subject 2017
School of Humanities and Social Science		
#27	World's Top 500 Universities in Social Sciences and Management	QS World University Rankings 2017

Research Assessment Exercise (RAE)

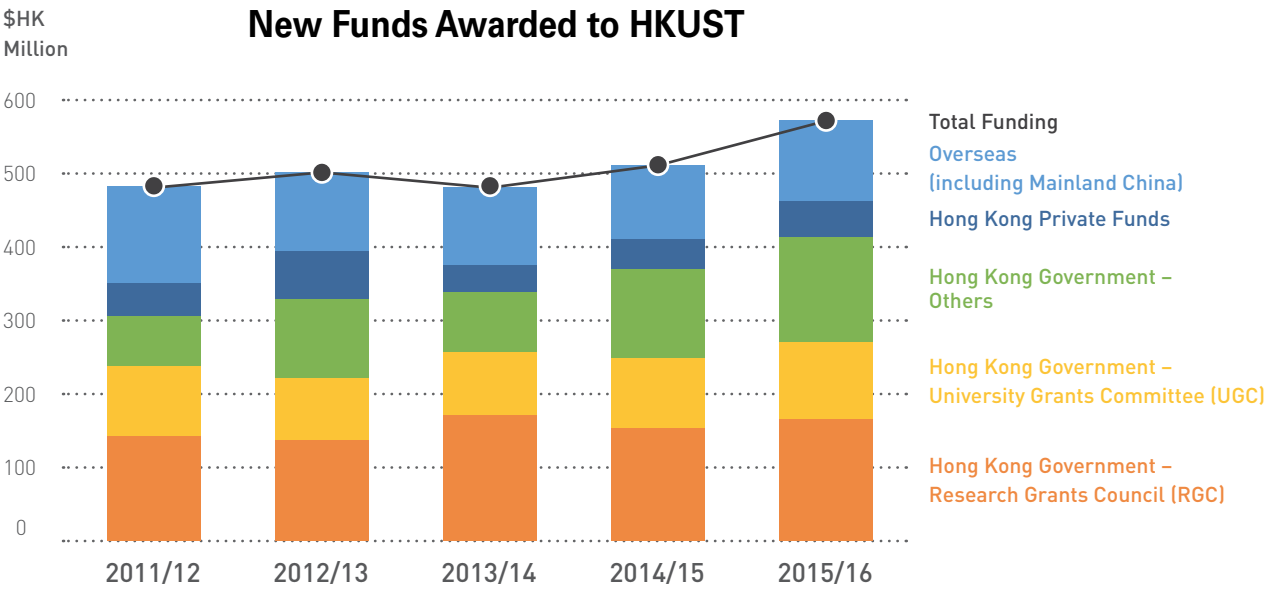
HKUST topped the institutional assessment with a remarkable 70% of its submissions (13 out of 19 cost centers or academic units) rated either "world leading" (4 star) or "internationally excellent" (3 star), according to the most recent RAE (2014), conducted by the University Grants Committee (UGC) in Hong Kong.



More information on RAE 2014 is available at http://www.ugc.edu.hk/eng/ugc/activity/research/rae/rae2014.html.

External Competitive Research Funding

(excluding Government block grants)



General Research Fund (GRF)

Consistently achieved the **highest success rate (45% in 2017/18)** among all local institutions.

Early Career Scheme (ECS)

Achieved the **highest success rate (57% in 2017/18)** among all local institutions.

Croucher Innovation Awards

Awarded **four out of 10** Croucher Innovation Awards in the past three years. Established in 2012, the Croucher Innovation Awards aim to recognize exceptionally talented scientists working at an internationally competitive level and to offer substantial research funding to these "rising stars".

Hong Kong PhD Fellowship Scheme (HKPFS)

Recruited the **largest number of awardees (26.8% in 2017/18)** among local universities for the sixth consecutive year. HKPFS is an award scheme established by the Hong Kong Government to attract top quality students to pursue PhD studies in Hong Kong.

Large-scale Competitive Research Programs (Current)

The Areas of Excellence Scheme, Theme-based Research Scheme and Collaborative Research Fund are large-scale group research grants awarded by Hong Kong Research Grants Council. The grants support internationally recognized research expertise in order to develop areas of excellence that can help maintain and enhance Hong Kong's overall development. They also support research areas of strategic importance for Hong Kong's long-term development, and encourage out-of-the-box cross-disciplinary projects. **Partner State Key Laboratory** and Hong Kong Branch of **Chinese National Engineering Research Center** are national research laboratories approved by the Ministry of Science and Technology.

Partner State Key Laboratory

Partner State Key Laboratory on Advanced Displays and Optoelectronics Technologies
PROF HOI SING KWOK

Partner State Key Laboratory of Molecular Neuroscience
PROF NANCY IP

Hong Kong Branch of Chinese National Engineering Research Center

Hong Kong Branch of Chinese National Engineering Research Center for Control and Treatment of Heavy Metal Pollution
PROF GUANGHAO CHEN

Hong Kong Branch of Chinese National Engineering Research Center for Tissue Restoration and Reconstruction
PROF BEN ZHONG TANG

Areas of Excellence Scheme

Cellular Mechanisms of Synaptic Functions and Plasticity in Health and Neurodegenerative Diseases
PROF NANCY IP

Mechanistic Basis of Synaptic Development, Signaling and Neuro-disorders
PROF MINGJIE ZHANG

Novel Wave Functional Materials for Manipulating Light and Sound
PROF CHE TING CHAN

Theme-based Research Scheme

Creation of Rechargeable Electron-fuels for Stationary Power Supplies and Electric Vehicles
PROF TIANSHOU ZHAO

Diagnosis and Prognosis of Intensifying Eutrophication, Hypoxia and the Ecosystem Consequences around Hong Kong Waters: Coupled Physical-biogeochemical-pollution Studies
PROF JIANPING GAN

Smart Urban Water Supply Systems (Smart UWSS)
PROF MOHAMED S GHIDAOUI

Understanding Debris Flow Mechanisms and Mitigating Risks for a Sustainable Hong Kong
PROF CHARLES WW NG

Stem Cell Strategy for Nervous System Disorders
PROF NANCY IP

Cost-effective and Eco-friendly LED System-on-a-chip (SoC)
PROF KEI MAY LAU

Collaborative Research Fund

Group Research Projects

Community and Population Aging in Hong Kong: An Extension of the Hong Kong Panel Study of Social Dynamics (HKPSSD)
PROF XIAOGANG WU

Study of Cooling Effect by Surface Treatment and its Application to Smart Green Buildings
PROF CHRISTOPHER CHAO

Study of Topological Phases in Condensed Matter and Cold Atom Systems
PROF KAM TUEN LAW

Coping with Landslide Risks in Hong Kong under Extreme Storms: Storm Scenarios, Cascading Landslide Hazards and Multi-hazard Risk Assessment
PROF LIMIN ZHANG

Dynamics of Soft Matter at Interfaces: Theory, Simulations and Experiments
PROF PENGER TONG

Total Municipal Organic Waste Management by Integrating Food Waste Disposal and Sewage Treatment (MOW-FAST)
PROF GUANGHAO CHEN

From Molecular Dynamics to Systems Biology: A Multi-scale Approach Tightly Integrating Simulation and Experiment to Quantitatively Analyze the Transcription Accuracy of RNA Polymerase II
PROF XUHUI HUANG

Elucidation of the Role of Pax7 in Muscle Stem Cells
PROF ZHENGUO WU

The Role of IL-33 in Synaptic Dysfunctions and Pathogenesis of Alzheimer's Disease
PROF NANCY IP

Research in Fundamental Physics: From the Large Hadron Collider to the Universe
PROF HENRY TYE

Equipment Projects

A Deep Reactive Ion Etching System for Nanosystem Fabrication
PROF ANDREW POON

A Platform for Measuring the Physical Properties of Quantum Materials
PROF JIANNONG WANG

Super-resolution Electron Microscopy Facility for Cross-disciplinary Materials Research
PROF NING WANG

A Mask-making System for Nanoelectronic Device and Circuit Fabrication
PROF MAN SUN CHAN

Research Infrastructure

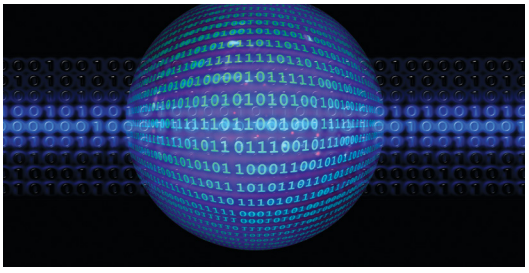
One of the distinctive features of HKUST's founding vision was to encourage interdisciplinary research from the University's earliest days. Recognizing the complexity of a globalized world and the cross-field challenges, such as climate change and sustainability, the University made key infrastructural provisions to assist top minds in working together to build solutions.

Research Institutes and Centers

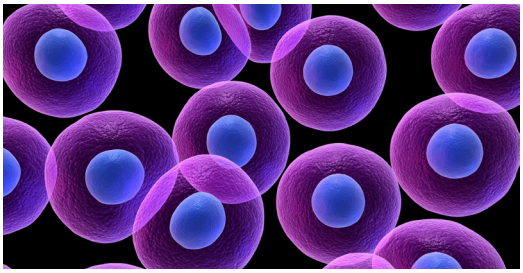
A centrally located Academic Building facilitates natural and frequent interaction among faculty members from different fields. The establishment of research institutes and centers, now numbering 12 and 37 respectively, fosters cooperation across traditional boundaries. Key research institutes are:

- Biotechnology Research Institute
- Big Data Institute
- Energy Institute
- Institute for Emerging Market Studies
- Institute for the Environment
- Robotics Institute
- William Mong Institute of Nano Science and Technology

Institute for Emerging Market Studies



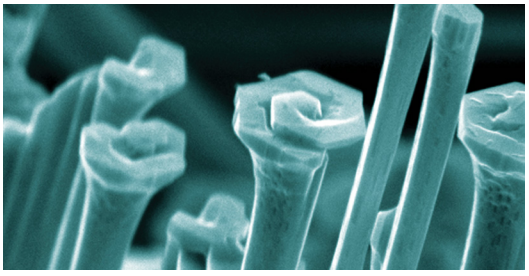
Big Data Institute



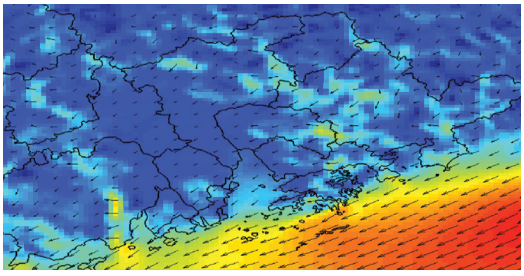
Biotechnology Research Institute

Energy Institute

Robotics Institute



William Mong Institute of Nano Science and Technology



Institute for the Environment

Central Research Facilities

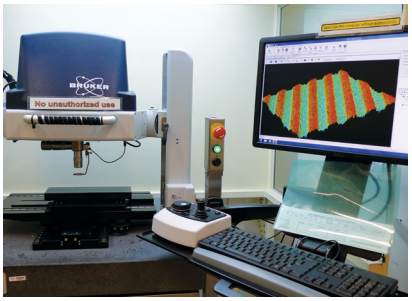
The Central Research Facilities are a pillar of the University's research infrastructure and play a vital and integral role in our multidisciplinary approach.

Advanced Engineering Materials Facility: houses leading research equipment to develop advanced engineering materials technology and its applications.

Animal and Plant Care Facility: humane care and husbandry, subject to rigorous HKUST-approved experimental protocols.

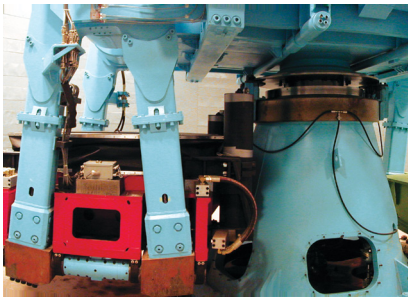
Biosciences Central Research Facility: provides cutting-edge communal equipment, training, and other activities to aid R&D in all areas of biological sciences.

CLP Power Wind/Wave Tunnel Facility: world-class experimental facility to test wind effects on structures and the environment.

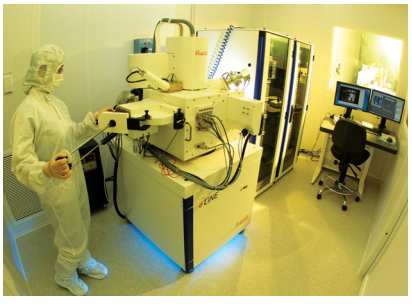


Design and Manufacturing Services Facility: offers unique services e.g. design and fabrication of sophisticated mechanical and electronic parts, nano measurements, CAE analysis, five-axis metrology, and reverse engineering.

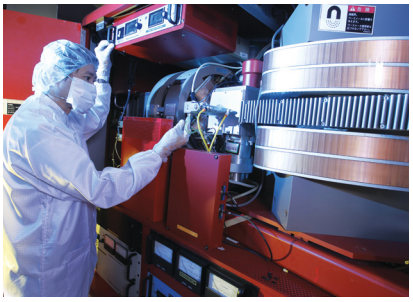
Environmental Central Facility: a key support platform equipped with environmental monitoring and analytical tools for atmospheric research.



Geotechnical Centrifuge Facility: physical modeling of engineering problems using the world's first in-flight 2D shaking table and a state-of-the-art four-axis robotic manipulator.



Materials Characterization and Preparation Facility: a core facility to serve research needs for the preparation, characterization, and analysis of various advanced materials.



Nanosystem Fabrication Facility: the first and only complete nanofabrication facility set up in a Hong Kong tertiary institution.

Design and Production by M&L www.mandl.asia

香 港 科 技 大 學

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY