Appendix

The 13 awarded CUHK scholars and their research projects

1. **Professor Dou Qi, Assistant Professor, Department of Computer Science and Engineering**

Project title: Federated medical image analysis on multi-centre heterogeneous data

Big data medical image analysis has been developing rapidly. With increasing concern about the protection of data privacy, federated learning (FL) is paving a new way for multi-centre collaboration in medical intelligence. However, due to different scanner vendors and data acquisition protocols, data is often inconsistent across centres. It currently not only affects the efficiency of federated training, but also affects the model's ability to be generalised, hindering the potential exploitation of big data. This project aims to innovate in federated learning approaches with theoretical analysis to address the challenge of data heterogeneity in both the FL model training and testing stages. The proposed research tasks include: 1) to develop a new FL training framework by innovating in local batch normalisation and constrained global aggregation with theoretical analysis of convergence, to achieve faster convergence and higher accuracy; 2) to improve generalisation performance of the federated model on heterogeneous testing data, using a novel strategy of personalised initialisation and self-supervised test-time adaptation with in-depth analysis of generalisation risk upper bound; 3) to experimentally demonstrate the general effectiveness of the proposed FL techniques on various medical image analysis tasks, including image classification, segmentation and detection. The success of this project will facilitate a revolution in next-generation, efficient, precise, trustworthy smart medical diagnosis systems using big data, which will have great scientific and clinical potential.

2. **Professor Duan Liting, Assistant Professor, Department of Biomedical Engineering**

Project title: Light-gated endoplasmic reticulum (ER) specific mechanostimulator for ER mechanobiology study

Cells in our body actively sense and respond to diverse mechanical information. It is critical to understand the underlying mechanisms, given that defects in mechanosensing and mechanotransduction are implicated in various diseases, including muscular disorders, cardiomyopathies, loss of hearing and cancer. Many efforts have revealed the roles of the plasma membrane and the cytoskeleton in cell mechanobiology. The connections of intracellular organelles to mechanical cues are only starting to emerge, including the nucleus, the Golgi and mitochondria. However, whether the endoplasmic reticulum (ER) is mechanosensitive remains unknown. The ER is a central organelle responsible for the synthesis of proteins

and lipids, ER-to-Golgi trafficking in the secretory pathway, and regulation of intracellular calcium (Ca^{2+}) levels. The investigation of how ER contributes to the perception of and response to mechanical stimuli is impeded by the lack of means to directly and precisely exert mechano-stimulation to ER inside live cells. Existing tools for mechanobiology studies, such as atomic force microscopes (AFM) and optical tweezers, cannot apply force towards specific intracellular organelles and suffer from low throughput. Therefore, it is imperative to develop a method for mechanostimulation over ER with high specificity, low cost and high throughput.

This project will develop the first ever method that can directly and specifically exert forces and deform ER structures inside living cells. In this strategy, molecular motors, a class of natural force-generating proteins, are recruited to the ER via genetically encoded light-activated protein-protein hetero-dimerisation. Therefore, the mechanical force provided by molecular motors can be applied to deform the ER by light. With non-invasiveness, ER specificity, reversibility, high throughput and spatiotemporal precision, this method of light-inducible ER deformation will greatly facilitate ER mechanobiology studies. Furthermore, using this novel optical strategy, the project will investigate ER mechanobiology by probing how forces will affect ER Ca^{2+} signals, ER stress and ER-to-Golgi trafficking. These results will shed light on the elusive mechano-sensing and mechano-responding properties of the ER.

3. Professor Gu Shen, Assistant Professor, School of Biomedical Sciences

Project title: Exploring the causes of selective neuronal vulnerability through *UBAP1* associated hereditary spastic paraplegia

Neurodegenerative diseases are a group of heterogeneous disorders characterised by the progressive degeneration of neuronal cells in the brain and spinal cord. One of their prominent features is neuronal selective vulnerability, a phenomenon demonstrating clinical manifestation in only specific region(s) of the brain and particular populations of cells. Hereditary spastic paraplegias (HSPs) are a group of genetic neurodegenerative diseases resulting from the length dependent axonal degeneration of the corticospinal upper motor neurons. Dismayingly, however, the molecular diagnosis of more than half of HSP patients and the pathogenicity mechanisms of most HSP genes remain unknown. Recently, the team and others independently identified a novel gene, ubiquitin associated protein 1 (*UBAP1*), as causative for autosomal-dominant HSP via whole exome sequencing analyses. All affected individuals showed highly comparable clinical presentations of non-syndromic HSP, with almost identical disease onset age in their childhood. Given the highly homogenous phenotype of the patients, UBAP1-HSP is a suitable disease model to decipher the underlying mechanism of selective neuronal vulnerability. Applying CRISPR/Cas9 genome editing tools, the team have established human embryonic stem cell lines and a mouse model harbouring the most common patient-specific recurrent *UBAP1* mutation. Using these *in vitro* and *in vivo* models, they will clarify the impact of *UBAP1* mutations on cellular function, and establish the progressive disease course of neuronal degeneration.

In addition, they will investigate the distinct pathogenicity among different cellular populations in mouse brains upon *Ubap1* mutation via single-nucleic transcriptome analysis. Understanding the pathogenicity and disease-causing mechanisms in UBAP1-HSP will shed light on the puzzle of selective neuronal vulnerability in neuronal degeneration diseases.

4. Professor Li Jingyu, Assistant Professor, Department of Management

Project title: How companies' and their business partners' digital strategies affect multi-dimensional performance: An attention-based view

Chinese companies try to improve performance and gain competitive advantages through digitisation. However, many companies fail to enjoy the expected benefits when they go digital. Three reasons may contribute to this phenomenon. First, companies ignore different attentional dimensions of digitisation and various impacts of performance. Second, very few companies consider their partners' attention to digitisation when designing their digital strategies. Third, companies seldom consider creating synergies by integrating their digital strategy with their partners'.

For a company to achieve the benefits of digitisation, it is crucial for its digital strategy to be compatible with its partners'. To solve the above issues, this project takes an attention-based view, proposing three dimensions of attention paid to digitisation and examining their impact on corporate performance. Secondly, the project addresses the interdependence between a focal firm and its business partners by exploring how its attention to digitisation may affect its partners. Thirdly, the project plans to examine a pathway by which a focal firm’s attention to digitisation might affect its performance and its partners' performance by affecting how much attention they pay to digitisation. Various contingencies are considered. This project provides conceptual guidance to help companies better select business partners and maximise the benefits of digitisation.

5. Professor Liao Chenxi, Assistant Professor, Department of Marketing

Project title: Game-Theoretic Analyses of Content Platform Marketing

The content industry is growing rapidly. Recently, the format of content creation and provision has evolved into one with numerous small-scale content creators based on large platforms. Compared with traditional products, the new content industry has several distinctive features, such as large heterogeneity across both content creators and consumers, the diversification of revenue streams, and great uncertainty about both content creation and consumption. Based on these features, this project aims to study the optimal strategies of multiple players in the content industry, such as platforms, content creators and content consumers, as well as the implications for platform profits, content creator surplus, consumer surplus and market structure. This project will investigate three research topics related to the

content industry. First, it will study the competition and cooperation between content creators on a single content platform. Second, it will examine the competition between multiple content platforms on both the supply and demand sides. Third, it will consider the coordination between upstream and downstream platforms in a content supply chain. By examining these topics, this project aims to contribute to the literature on the content industry and platform marketing, and provide managerial insights for content platforms, content creators, content consumers and policymakers.

6. Professor Ma Xin, Research Assistant Professor, Department of Mechanical and Automation Engineering

Project title: Design, optimisation and human-machine cooperation control of multi-layer, multi-form, rigid-flexible, hybrid structure

To meet the urgent need for accurate, smart medical treatment in China and solve surgical sinus robots' problems of poor performance in physical accessibility, flexibility, bending and torsional stiffness, shape and force sensing, operation accuracy and safety, this project studies the design and human-machine cooperation control method of multi-layer, multi-form, rigid-flexible hybrid structure/dimension. The sinus is narrow and surgical operations inside it are complex. To overcome these difficulties, this project proposes a surgical robot based on multi-layer, multi-form, rigid-flexible hybrid structure (MMRHS); builds a MMRHS static model that considers factors including structural flexibility and motion pair interface friction; proposes a MMRHS performance analysis and optimisation method that considers workspace, bearing capacity, bending and torsional stiffness; and proposes a computer vision technology-based error calibration method for surgical sinus robots that enables them to be precisely controlled. To overcome the difficulties of poor shape and force sensing in narrow, confined spaces, the project proposes a MMRHS real-time shape and force sensing method based on the constraints of the static and kinematic models, and feedback from computed tomography (CT) images. A surgeon-sinus robot cooperation control method is proposed and its reliability and robustness are validated by experiment. The research results can provide theoretical support for the application and control of flexible hybrid structure in accurate, smart medical treatment in China.

7. Professor Wang Wuming, Research Assistant Professor, School of Biomedical Sciences

Project title: Elucidating the roles of Pten in cardiac fibroblast generation and myocardial fibrosis

Cardiac fibrosis is observed in nearly every form of myocardial disease and is a major cause of heart disease. In response to various heart injuries, cardiac fibroblasts will become activated as the major mediator cells in pathological remodelling. The generation and activation of cardiac fibroblasts are important for

the repair of heart injury. Currently, the origin and differentiation mechanism of cardiac fibroblasts remain unclear, which creates challenges for further development of anti-fibrosis therapy. The team's preliminary data showed that phosphatase and tensin homolog (Pten) loss suppressed the generation of cardiac fibroblasts from embryonic stem cells. The expression of a series of cardiac fibroblast markers was decreased, and the quantity of the induced cardiac fibroblasts was also reduced in Pten knockout group. Intriguingly, RNA-seq data showed that the expression of activated cardiac fibroblast markers was also affected by Pten knockout. The team suppose that Pten is involved in regulating the cardiac lineage differentiation, and Pten deficiency suppresses the generation of cardiac fibroblast generation and significantly reduces myocardial fibrosis, but the regulatory mechanism needs to be further studied. The proposed study aims to elucidate the roles of Pten in regulating the generation and activation of cardiac fibroblasts, and understand the mechanism of cardiac fibrosis. It will provide a theoretical basis for potential anti-fibrosis therapy.

8. Professor Wu Jing, Assistant Professor, Department of Decision Sciences and Managerial Economics

Project title: Global supply chain risks and restructuring: An empirical study

The risks faced by global supply chains have been a hot topic in supply chain management research in recent years. The extant literature on the restructuring of supply chain management under exposure to risk lacks empirical evidence. This project aims to identify the risks faced by the global supply chain and provide measures to counter shocks resulting from these risks using multivariate regression analysis and tensor factor modelling methods. This project first identifies global supply chain risks, both natural and man-made. Next, it provides mitigation and response options from various perspectives. The first is the regionalisation of global supply chains, replacing long chains with short ones, such as China's "One Belt, One Road" initiative, taking advantage of the depth of the China Mainland and regional comprehensive economic partnership agreements that promote supply chain localisation. The second is to create a capital future-oriented chain, which exchanges capital, information, standards of control and integration of digitisation.

9. Professor Yan Yangqian, Assistant Professor, Department of Physics

Project title: Equation of state and thermodynamic properties of the unitary Fermi gas

Scale invariant strongly interacting Fermi gases, i.e. unitary Fermi gases, could be applied to systems of various sizes such as nuclei, ultracold gases and neutron stars. Thus, they are of common interest to nuclear physicists, condensed-matter physicists, and atomic and molecular physicists. The equation of state of unitary Fermi gases in harmonic traps has been measured in ultracold atomic experiments. A fit to the high temperature regime yields the virial coefficients from the virial

expansion. The most recent numerical results obtained from first principles do not agree with the experiment within error bars. Nowadays, unitary Fermi gases can be successfully realised in box traps. Tan contact etc has been measured. Without local density approximations, the equation of state can be measured more accurately in box traps. This project plans to (i) use a bottom-up approach, i.e. the path integral Monte Carlo method, to obtain Tan contact etc as a function of the temperature, and analyse the finite-size effect; (ii) use a top-down approach, i.e. improve the algorithm that calculates the virial coefficients in free space, improve the precision and calculate higher-order virial coefficients; (iii) systematically study the approximations to the equation of state of the unitary Fermi gas and point out the underlying physics.

10. Professor Yan Zhenyu, Research Assistant Professor, Department of Information Engineering

Project title: Context-aware sensing using indoor powerline electromagnetic radiation

Internet-of-Things (IoT) systems, as the basis of the Internet-of-Everything, fulfil various functions in people's everyday lives and in manufacturing processes. Context-aware sensing is a fundamental technology for interconnection among humans, machines and the environment. However, due to diverse hardware and limited computing resources, designing an infrastructure-free, easy-to-use sensing technology for heterogeneous IoT devices is a significant challenge. Radiated from alternating-current powerlines, powerline electromagnetic radiation (EMR) exists pervasively in indoor environments and can be sensed without extra infrastructure. This project aims to leverage powerline EMR to solve the fundamental research problems in context-aware sensing, and: 1) develop a powerline EMR sensing technology to capture EMR from different locations in the human body using off-the-shelf wearables; 2) develop a powerline EMR sensing technology to collect the environmental radiation using heterogeneous IoT devices; 3) leverage powerline EMR from the body or the environment for context-aware applications concerning user activity, environment and identity. The output of this project will provide theoretical proof and system verification for inter-device, context-aware sensing applications, and enable massive IoT application in the future.

11. Professor Yang Yang, Assistant Professor, School of Hotel and Tourism Management

Project title: Environmental pollution and consumption behaviour in the digital era: Investigation of causal effects, mechanisms and environmental governance

In the context of promoting green and low-carbon development, and leveraging the power of the digital economy, examining the impact of environmental pollution on consumption patterns and behaviour is an important academic field and has significant policy implications for promoting consumption growth, the digital economy and a green transition. However, due to the challenge of identifying

exogenous variation in environmental pollution and the lack of micro-level online consumption data, the existing literature lacks evidence directly relating air pollution to digital consumption.

To fill this gap, the proposed project uses a proprietary individual level online consumption dataset from the largest e-commerce company in China to provide new empirical evidence on the causal relationship between ambient air pollution and online consumption behaviour. The project addresses the endogeneity of air pollution in affecting household consumption by exploiting plausibly exogenous variations in air quality caused by China's Huai River heating policy. There are three primary objectives: first, to examine the impact of air pollution on consumption patterns and consumption behaviour; second, to study the underlying mechanisms through which air pollution affects digital consumption and estimate the willingness to pay for clean air; third, to provide policy suggestions to promote the energy revolution and develop the digital economy.

12. Professor Zhang Jie, Research Assistant Professor, Department of Chemistry

Project title: Direct nucleophilic substitution reaction of cage B-H bonds in o-carboranes

Carboranes, 3D analogues to benzene, are a class of boron hydride clusters in which one or more of the BH vertices are replaced by CH units. Due to their unique σ-aromaticity, remarkable thermal and chemical stability, carboranes are finding wide applications as useful functional building blocks in medicine, materials and coordination/organometallic chemistry. Currently, the challenging issue in the field of carborane chemistry is how to prepare functionalised carborane derivatives with high efficiency and selectivity. The construction of cage B-heteroatom bonds is generally realised via electrophilic substitution of B-H bond or transition metal catalysed B-H functionalisation. This project plans to functionalise carboranes at selected B-vertex through direct nucleophilic substitution of cage B-H bond. In the presence of Lewis base ligand, it will explore direct nucleophilic substitution of 1,2-disubstituted carboranes bearing electron-withdrawing groups with various heteroatom nucleophilic reagents for efficient construction of B-heteroatom bonds at adjacent B(3,6)-, middle B(4,5)- or distal B(9,12)-vertices. It is anticipated that this research will provide a new toolbox for the preparation of B-substituted carborane derivatives, which will have potential applications in medicine and materials, enhancing our fundamental understanding of aromatic nucleophilic substitution reactions in organic chemistry.

13. Professor Zhang Tao, Research Assistant Professor, Department of Obstetrics and Gynaecology

Project title: Unraveling the regulatory effects of prodrug epigallocatechin-3-gallate (pro-EGCG) on myeloid-derived suppresser cells (MDSCs) to suppress the development of endometriosis

Endometriosis is a common gynecological disorder, and has become a global public health challenge, leading to tremendous financial and social burdens due to the lack of efficient treatment options. The team's previous study found that endometriosis was correlated with a higher percentage of myeloid-derived suppressor cells (MDSCs) in peripheral blood and peritoneal fluid. MDSC depletion or blocking the cells' migration was able to inhibit the growth of endometriosis in a mouse model, suggesting MDSCs drive the development of endometriosis and might be a potential therapeutic target. The results of the pilot study showed that a prodrug of green tea epigallocatechin-3-gallate (pro-EGCG) with no side effects on hormones can significantly and competently inhibit the development of endometriosis in the mouse model. Therefore, taking advantage of in vitro experiments to imitate the abdominal microenvironment in endometriosis and in vivo animal models, this study intends to investigate the effects of pro-EGCG on MDSCs and its mechanisms, aiming to explore whether pro-EGCG inhibits the progress of endometriosis by targeting MDSCs to ameliorate the peritoneal microenvironment. The project will provide scientific evidence for the potential application of pro-EGCG in endometriosis, and clues for the development of immunotherapies for endometriosis.