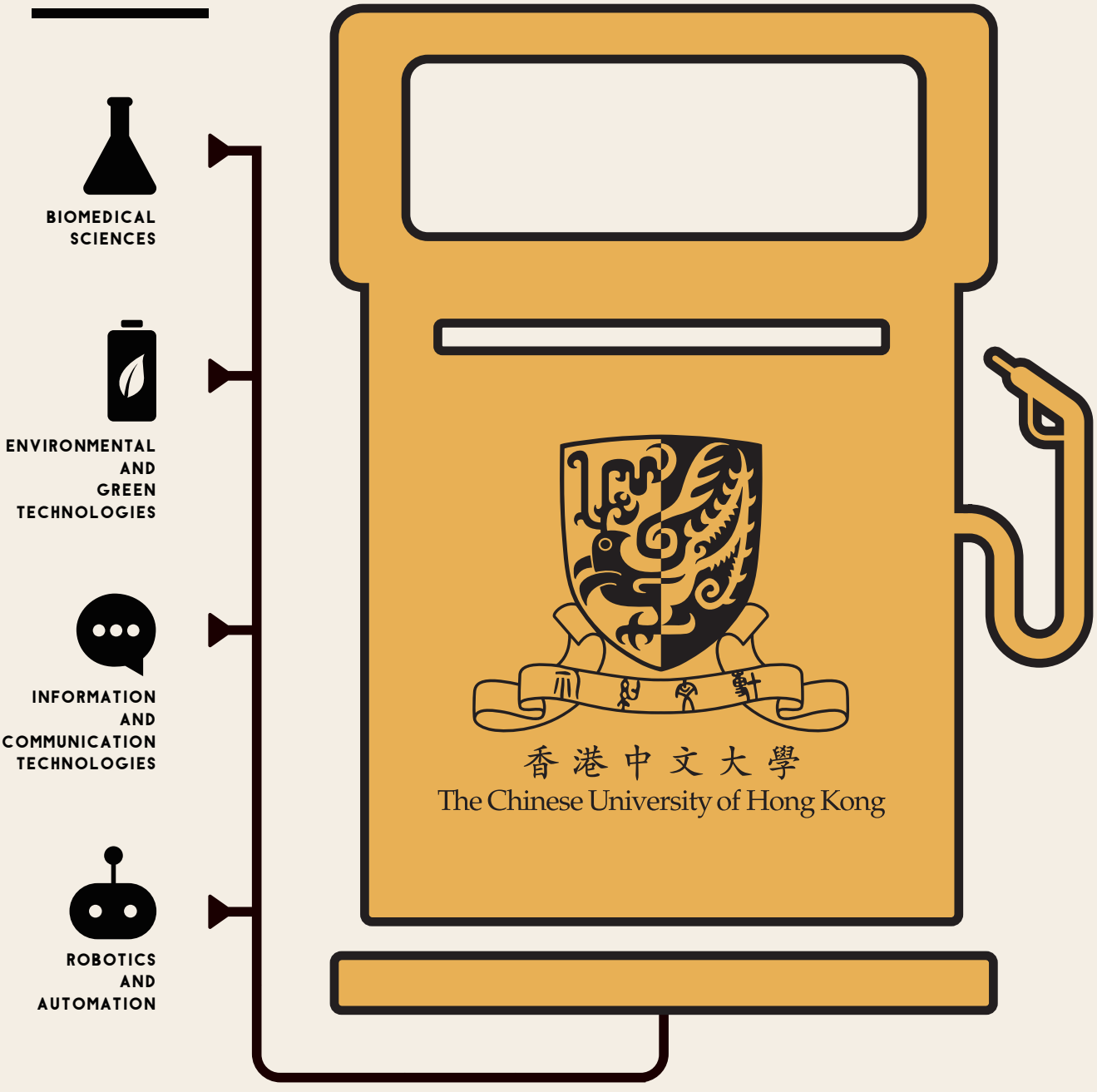
2017–2018

INNOVATION

FOR BETTER LIFE



PREFACE

Innovation for Better Life is the theme of this booklet. Being a forward-looking comprehensive research university, The Chinese University of Hong Kong (CUHK) not only pursues excellent innovative research, but also strives to transfer the fruitful research result into practical form and eventually to be commercialized.

This year, all the listed projects are ready for demonstration or even commercialization. Some are / will be adopted by the government department or public service unit; some are being developed into start-up companies.

Centre for Innovation and Technology (CINTEC), as a technology transfer arm of CUHK under the Faculty of Engineering, is pleased to share the latest CUHK practical research results with you. We aim to serve as a bridge between the university and the industry, facilitate communications and collaboration between CUHK research teams and the industry, as well as promoting innovation through technology transfer to the society.

If you would like to read an electronic version of the projects listed, please visit the website: exhibition.cintec.cuhk.edu.hk/exhibition. Furthermore, if you have any enquiries, please contact us by phone: (852) 3943 8221 or email: enquiry@cintec.cuhk.edu.hk.

Thank you for your interest in the innovations of CUHK.

Prof. WONG Kam-fai
Director
Centre for Innovation and Technology
The Chinese University of Hong Kong

「創新為更美好生活」是本書刊的主題。作為一所具前瞻性的研究型綜合大學，香港中文大學 (中大) 不但追求卓越的創新科研，還致力把豐碩的研究成果轉化為實用方案，並最終成為商品。

今年，所有納入於本刊的項目，都有實際成果可以示範操作甚或商品化，有些已經 / 將被政府部門或公營單位採用；有些則正發展成初創公司。

創新科技中心作為隸屬於中大工程學院的技術轉移部門，樂意與您分享中大的最新應用科研成果，我們旨在結連大學與業界，以促進中大研究團隊與業界的交流與合作為己任，同時亦透過向社會和業界的技術轉移，推動創新。

如您想參閱本刊項目的電子版本，請瀏覽網頁 exhibition.cintec.cuhk.edu.hk/exhibition。此外，若有任何查詢，請與我們聯繫，電話：(852) 3943 8221 電郵：enquiry@cintec.cuhk.edu.hk。

謹此感謝您對中大創意發明的興趣。

香港中文大學
創新科技中心主任
黃錦輝教授

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BIOMEDICAL SCIENCES
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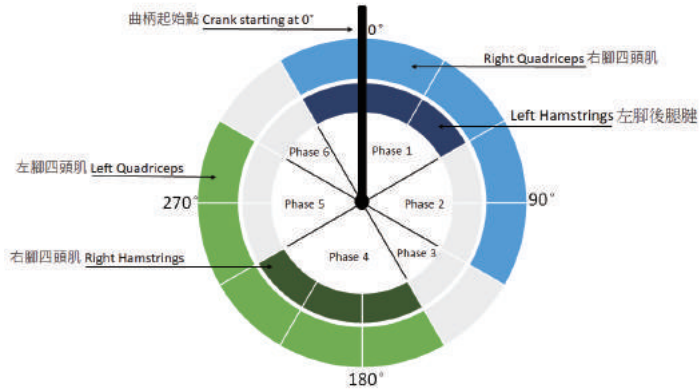
電刺激互動復康單車
FUNCTIONAL ELECTRICAL STIMULATION (FES) CYCLING SYSTEM FOR REHABILITATION

中風人士或下肢殘疾人士的復康訓練
Rehabilitation for stroke survivors or individuals with lower-limb disability



Our cycling system is also suitable for person with spinal cord injury to perform rehabilitation exercise both at outdoor and indoor environment
我們的復康單車同時適合脊髓損傷患者在室外或室內進行復康訓練

The Functional Electrical Stimulation (FES) cycling system is designed for the lower-limb rehabilitation of stroke survivors or the elderly. The system was a six-phase-angle-driven process using real-time crank angle to generate the electrical pulses to targetted muscle and trigger muscle contraction in accordance with the user' s voluntary intention for cycling, hence promoting functional recovery of the lower limbs.

電刺激互動復康單車訓練專為下肢殘疾復康而設計，適合中風人士和長者的復康訓練。系統根據用戶踏單車的自主意識，在特定的角度向目標肌肉輸出電脈衝以引起肌肉收縮，從而促進下肢功能的康復。

- While gait training requires residual balance and lower limb function which are often absent in the early rehabilitation stage, cycling provides a safe and effective option with less initial requirement
- The exercise can be performed in both indoor and outdoor environment. It encourages users to conduct more exercise, which helps to enhance their muscle strength and improve their blood circulation and mobility
- 患者進行一般步行式的步態訓練，需要有一定的平衡力和下肢功能，這對康復初期的患者來說十分困難。復康單車為他們提供了一個體能需求較低但卻安全有效的選擇
- 訓練可以在室內或室外環境進行，有助鼓勵用戶進行更多的運動，以增強他們的肌肉力量和改善他們的血液循環和活動能力

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聽力障礙基因捕獲芯片研發及臨床應用
RESEARCH AND DEVELOPMENT OF HEARING IMPAIRMENT-TARGETED EXOME PANEL FOR CLINICAL APPLICATION

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Collaboration with Angsana Molecular & Diagnostics Laboratory(HK) Ltd, Clinical Genetic Service, Department of Health, Havard Medical School, Paramount Medical Center and Suzhou Municipal Hospital
合作夥伴包括Angsana Molecular & Diagnostics Laboratory(HK) Ltd, 香港特別行政區衛生署醫學遺傳科, 哈佛醫學院, 領峰醫務中心及蘇州市立醫院

Hearing impairment is one of the most common birth defects worldwide with the incidence of 1 in 500. In China, it has been estimated that over 27 million people are with hearing and speech disabilities. More than 60% of these hearing impairments are caused by genetic factors. The genetic diversity of hearing impairment precludes effective genetic diagnosis. However, only 4 hearing mutations were screened at the Department of Health.

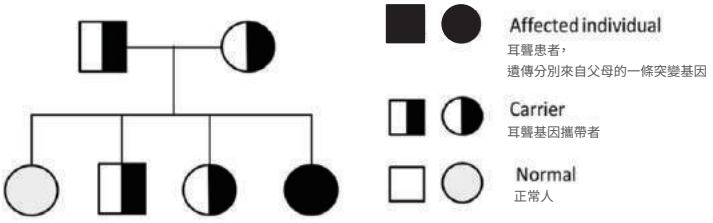
Based on our previous study, the combination of in-solution capture and massively parallel sequencing is a high throughput and comprehensive approach for detection of hearing impairment gene mutations. Our project aims for providing a most clinical relevant and comprehensive genetic testing covering 125 genes by applying this state-of-the-art NGS (Next-Generation Sequencing) technology in the market.

聽力障礙是新生嬰兒中最常見的出生缺陷之一，約每500名新生嬰兒中就有一名聽力障礙患者。在中國，聽力語言殘疾患者超過2700萬，當中60%是由遺傳因素引起的。聽力障礙相關的基因多種多樣，以致基因診斷異常困難，而目前香港衛生署僅能檢測四個基因。

我們的前期科研發現，將「液相捕獲技術」以及「二代測序」合併，是一種靈敏度高、覆蓋全面的基因突變檢測方法。本項目旨在優化該技術，設計一款市面上覆蓋基因數量最豐富和靈敏度高的聽力障礙致病基因檢測試劑盒，能夠覆蓋目前125個已知的聽力障礙致病基因。

- Improved ability to diagnose hearing loss patients and to carry out prenatal diagnosis and preimplatation diagnosis for their families by expanding the detection list from 4 genes to 125 genes
- Initiate early intervention to prevent delayed language acquisition in childhood hearing loss, allowing better social and academic adoption
- Identification of causative mutations in patients with syndromic hearing loss enables prevention or early detection of associated symptoms

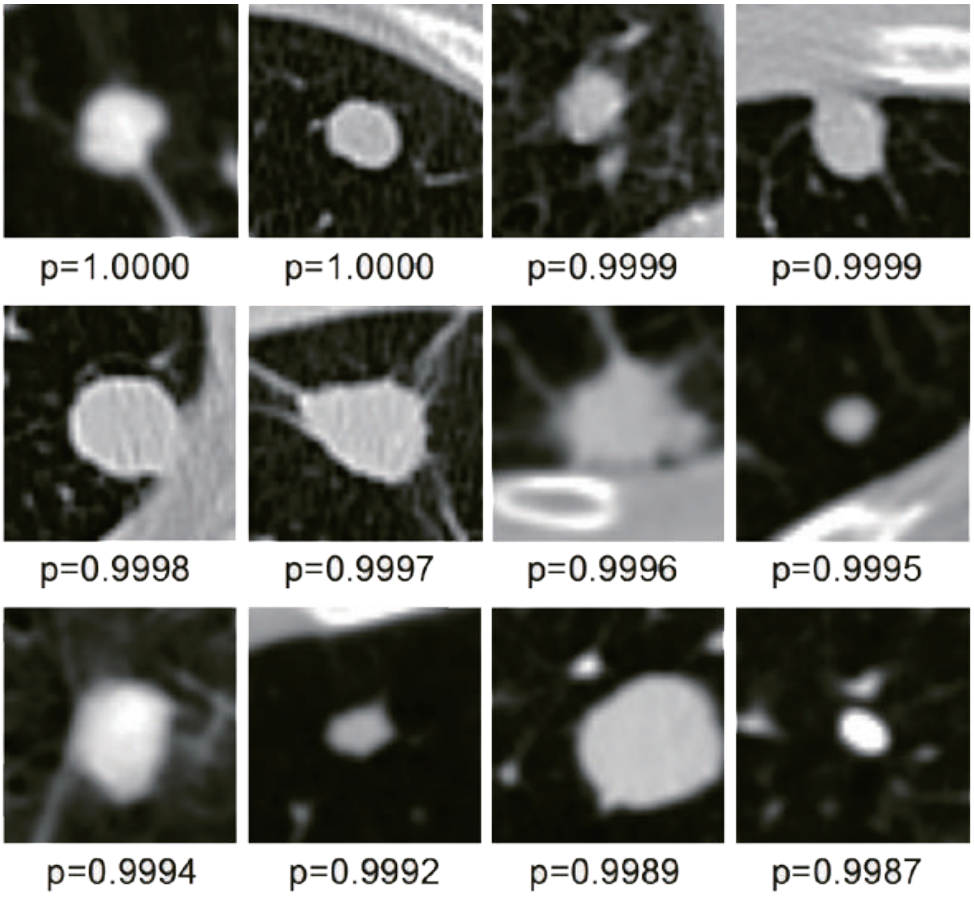
- 將聽力障礙基因的覆蓋數量由4個擴展到125個，為聽力障礙患者提供更好的診斷，並為患者家人提供更好的產前診斷和胚胎植入前診斷
- 為兒童聽力障礙患者及早提供干預及治療，避免延誤了他們的語言學習，從而改善社交和學業發展
- 診斷出聽力障礙患者的致病基因，有助及早預防或檢測相關的症狀

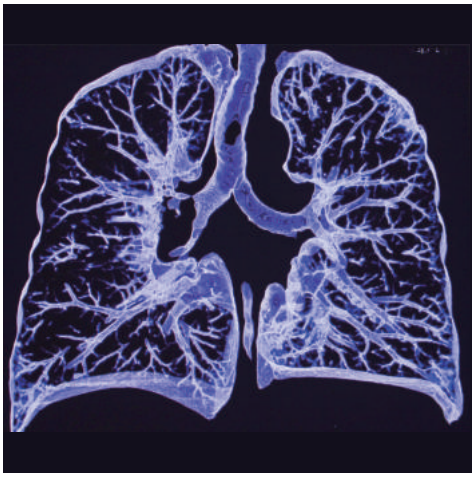


Carriers are at risk of transmitting the defected gene to their offspring
耳聾基因的攜帶者存在將突變基因遺傳給後代的風險

早期肺癌的自動化篩查
AUTOMATIC SCREENING OF PRIMARY LUNG CANCER

基於神經網絡技術自動檢測肺結節病變
Automated detection of pulmonary nodules via deep neural networks





Lung nodule predictions with deep neural networks
透過神經網絡技術預測肺結節病變

Lung cancer has been the leading cause of cancer deaths worldwide. Visual inspection of lung tumors through medical imaging is one tedious and time-consuming task for radiologists and doctors. We propose a novel deep-learning-based framework with 3D convolutional networks for screening of primary lung cancer by automatically detecting pulmonary nodules from low-dose CT (Computed Tomography) images. Time and cost for screening will be significantly reduced and hence it will be beneficial to early diagnosis and treatment of lung cancer.

肺癌是全球癌症死亡率最高的疾病之一。放射治療師或醫生要從醫學影像中檢查肺部有沒有腫瘤，不但枯燥乏味，且極之費時。我們提出基於深度學習技術的自動化解決方案，利用三維卷積神經網絡，從低幅射劑量電腦斷層掃描影像中自動檢測肺部的小結節。篩查的時間和成本將顯著降低，有助及早診斷及治療肺癌。

- Our proposed framework consists of two stages: 1) candidate screening, and 2) false positive reduction
- Different from previous standard deep learning based methods, we try to tackle the severe hard/easy sample imbalance problem in medical datasets and explore the benefits of localized annotations to regularize the learning
- 我們提出的方案包含兩部分內容：1) 可疑位置查找 2) 假陽性排除
- 有別於之前的深度學習方案，我們採用先進的訓練技巧，解決數據當中易測樣本與難測樣本數量不平均的問題，並增強模型的優化程度，從而提高模型的自動識別能力

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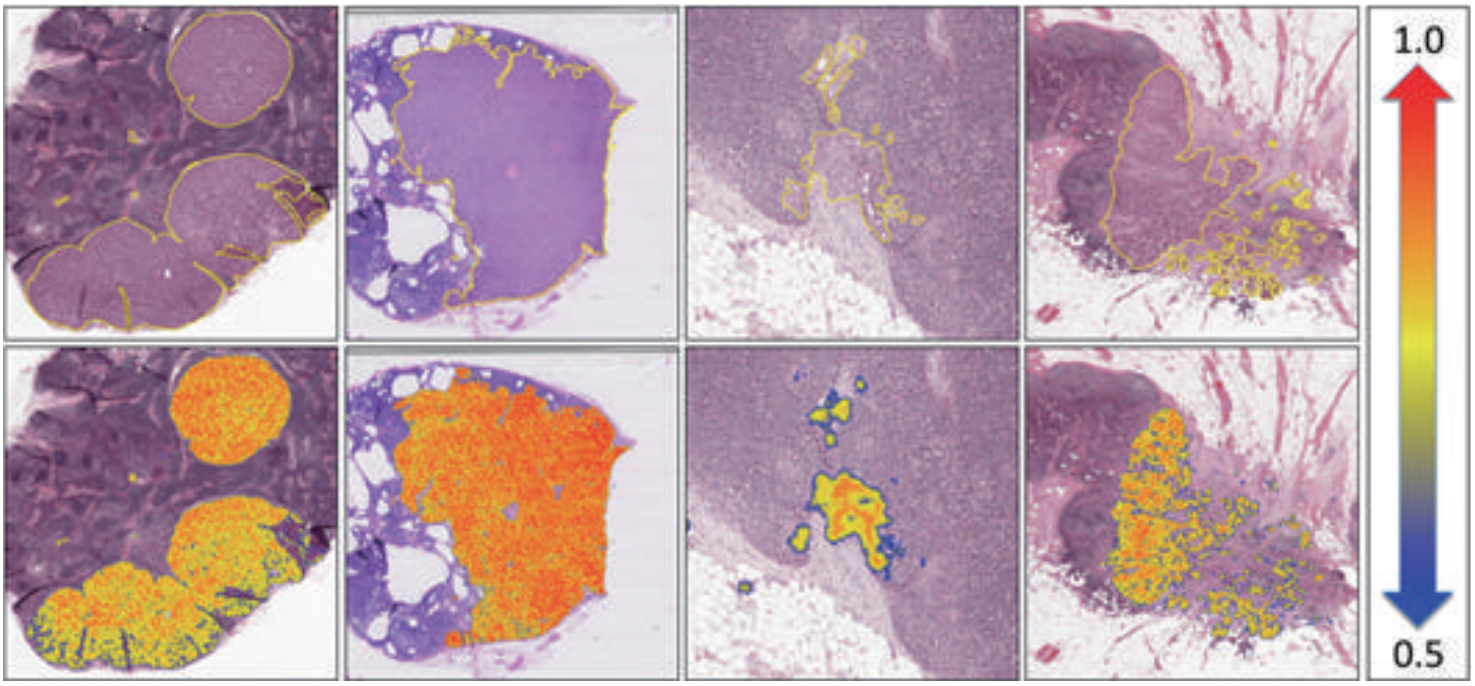
乳腺癌病理影像的自動化分析技術
AUTOMATIC ANALYSIS OF BREAST CANCER HISTOLOGY IMAGES

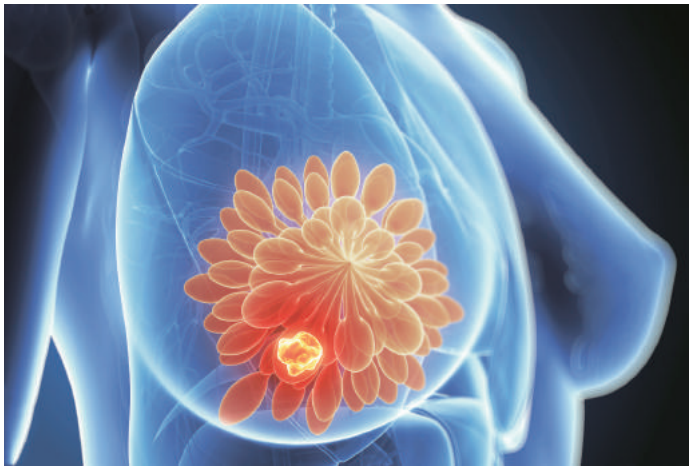
基於深度學習技術從乳腺癌病理影像中自動檢測乳腺癌轉移
Using deep learning technology to automatically detect metastasis in breast cancer histology



Metastasis detection of breast cancer histology images with cascaded convolutional neural networks
基於深度學習技術從乳腺癌病理切片中檢測癌症轉移區域

The detection of lymph node metastasis gives an important aggressiveness indication of the invasive breast cancer. However, visual inspection relying on pathologists is time-consuming and expensive. To enhance the diagnosis of breast cancer, we propose a fast and robust method to detect mitosis by designing a novel deep cascaded convolutional neural network.

淋巴結轉移是診斷乳腺癌的關鍵指標，但目前的組織切片病理分析大多依賴病理醫生的檢測和判斷，需時長且成本高。我們提出基於深度學習技術的自動化解決方案，可以從組織切片中準確快速檢測有絲分裂細胞，輔助乳腺癌的診斷。



The deep cascaded neural network is composed of two components:

- First, by leveraging the fully convolutional network, a coarse retrieval model will identify and locate the candidates of mitosis while preserving a high sensitivity
- Then, based on these candidates, a fine discrimination model is developed to further single out lymph node metastasis.

基於深度學習技術的解決方案包含兩部分

- 首先，使用全卷積技術對組織切片全圖進行粗略但高靈敏度的篩查，篩查出有絲分裂細胞
- 然後，使用具有高分辨能力的神經網絡從篩查對象中遴選出淋巴結轉移的真實位置。

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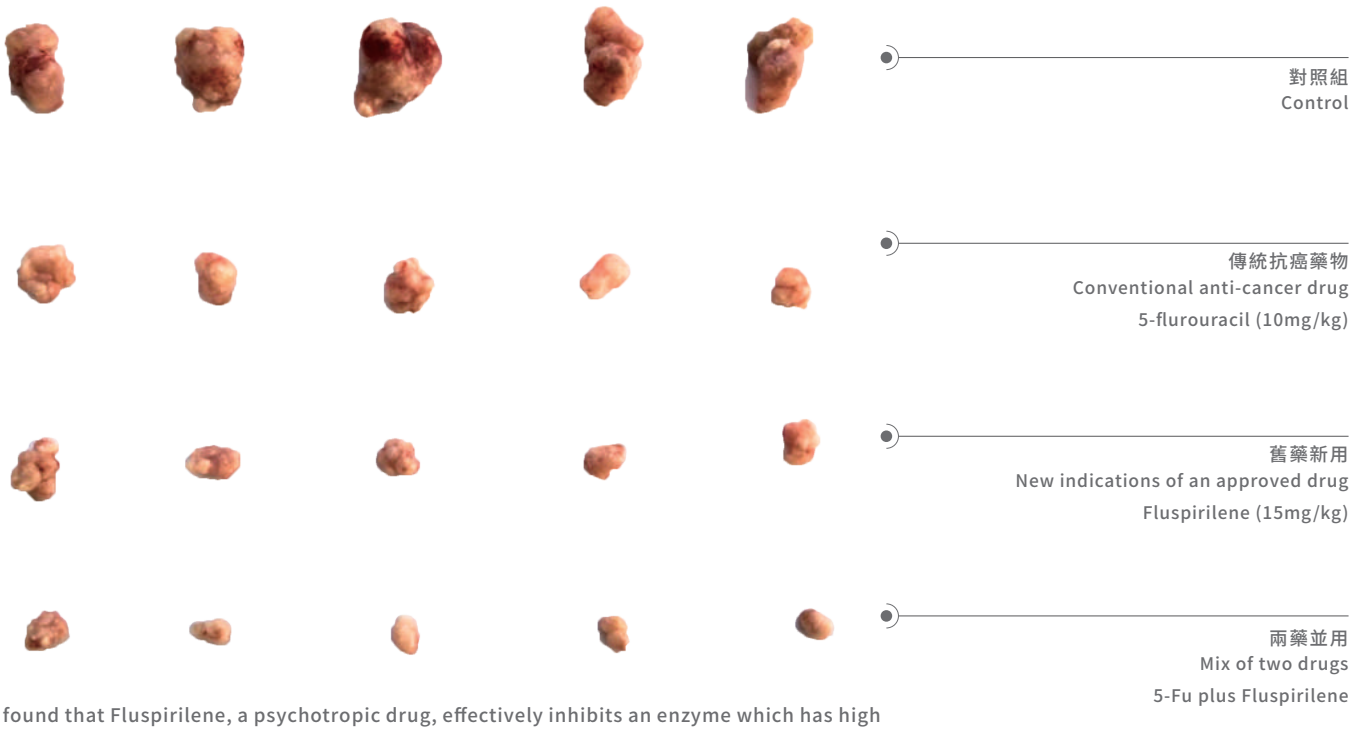
電腦自動化舊藥新用
COMPUTATIONAL DRUG REPURPOSING

尋找已獲臨床認可藥物的新用途，以治療特定病人的癌症
Identifying new indications of clinically approved drugs for treating cancer specific to a particular patient



We found that Fluspirilene, a psychotropic drug, effectively inhibits an enzyme which has high level expression in a variety of cancers. Its performance in reducing the weight and volume of tumors is similar to that of a conventional anti-cancer drug.
我們發現一種精神科藥物氟司必林能有效抑制一種活躍於多種癌症的蛋白酶。它能夠減小腫瘤的重量和體積，效果與傳統抗癌藥物相若。

Liver, colon, lung and bladder cancers are common causes of deaths worldwide. Surgical resection and conventional chemotherapy and radiotherapy are likely to fail because of tumor recurrence and resistance. Hence, finding appropriate medications on a personal basis is now being intensively researched. We have recently developed a series of computer software to realize automatic identification of novel indications of approved drugs for the treatment of patient-specific cancer subtype via targeting the pharmacological oncoprotein mutants of a particular patient. In real-world applications, by utilizing the in-house in silico tools, we managed to reposition several clinically approved drugs as anticancer agents and filed patent applications for five of them.

肝癌、大腸癌、肺癌及膀胱癌是全球常見的致命疾病。切除手術、化療和電療的失敗率很高，因為腫瘤會復發而且產生抗藥性。因此，不少研究正展開去尋找合適特定病人的治療方法。最近，中大開發了一系列能夠自動尋找認可藥物新用途的電腦軟件，針對帶有特定變異的藥理致癌蛋白進行藥物篩選，找出舊藥的新用途去治療特定病人的子類癌症。我們成功在現實應用中透過我們的研究方法找到幾個藥物作為抗癌藥，並為當中五個申請了專利。

- Repurposing existing drugs greatly reduces the cycle and cost of the research and development of new drugs
- The development risk is reduced since existing drugs are approved and have been shown to be safe in late-stage trials
- In a general sense, the applicability domain of our toolset could be expanded to treating any kind of diseases
- 舊藥新用可以大大縮短研發新藥的週期並減低其成本
- 由於舊藥已得到認可，其安全性亦獲後期臨床測試證實，研究的風險大大降低
- 我們的技術基本上可以擴展至治療任何一類疾病

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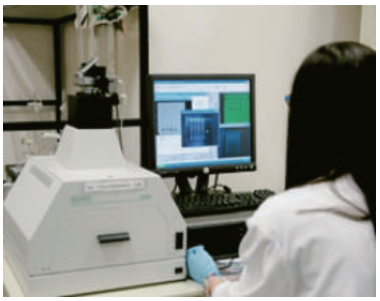
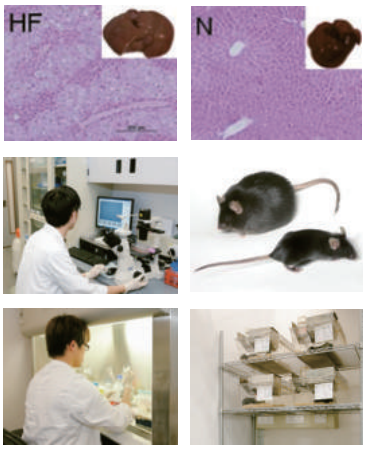
治療代謝綜合症的創意性多靶向中西草藥配方
AN INNOVATIVE MULTI-TARGETED HERBAL FORMULA FOR MANAGEMENT OF METABOLIC SYNDROME

EXPERIMENTAL PROCEDURES



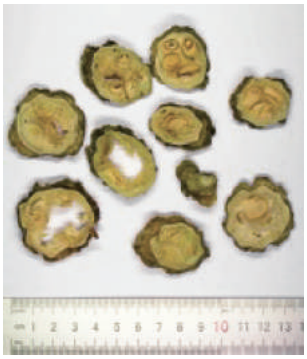
Chemical authentication
草藥化學鑑定

Herb extraction
草藥提取



Investigation of the biological activities using our scientific platform of cells and animals in the laboratory
以動物和細胞平台進行針對抗體胖、降血脂、降血糖，和抗脂肪肝成效測試

HERBS TO BE STUDIED



Momordica charantia
苦瓜

Schisandrae Fructus
五味子

Crataegus Fructus
山楂

Milk thistle
奶薊

Metabolic syndrome (MetS) refers to the clusters of risk factors that lead to increased episodes of cardiovascular disease. These risk factors include obesity, non-alcoholic fatty liver (NAFLD), hyperlipidemia, hyperglycemia, etc. MetS is becoming more common in Hong Kong, with a prevalence of 19.2% in male, and 23.2% in female aged 50 years or above.

Since the pathogenesis of MetS has multiple metabolic origins, pharmacological approaches often consist of different drugs which target at individual risk factors: lipid-lowering drugs, antihypertensive drugs, hypoglycemic drugs or weight-loss agents. Yet, this combination of drugs would pose various side effects. Functional foods or nutraceuticals have therefore attracted great attention. The aim of this project is to develop a multi-targeted herbal health supplement for the management of MetS, focusing on obesity, hyperlipidemia, hyperglycemia, and NAFLD.

代謝綜合症是多種代謝成分(包括:肥胖、非酒精性脂肪肝、高血脂、高血糖等)異常聚集的病理狀態，可增加患心腦血管疾病的風險。代謝綜合症於香港變得愈來愈普遍，其中50歲以上的男性和女性患病率分別為19.2%和23.2%。

由於代謝綜合症是多種病理狀態集結的疾病，發病機制有多種代謝起源，因此經常需要使用多種分別針對不同病理狀態的藥物作組合治療，包括降脂藥、抗高血壓藥、降血糖藥或減肥藥等。但這些藥物組合會構成各種副作用，故此，功能食品或天然保健品成為研究的焦點。本項目開發治療代謝綜合症的多靶向中西草藥配方，主要針對肥胖、高血脂、高血糖和非酒精性脂肪肝。

- The multi-targeted herbal health supplement is developed through evidence-based research
- Experiments are performed to identify the efficacy and mechanism of action of these selected herbs using in vitro and in vivo platforms
- Results obtained will allow the initiation of a pilot clinical trial on patients with MetS in Hong Kong
- 中西草藥配方的研究以生物科技證據作為基礎
- 以細胞培養體外實驗和小鼠體內測試確定中西草藥配方產生的效果和作用機制
- 以上的測試結果將有助我們開展以代謝綜合症患者為對象的初期臨床測試

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合作夥伴為昶金有限公司

ENVIRONMENTAL & GREEN TECHNOLOGIES
環保和綠色技術

Use Of Remote Sensing Techniques In Ground Deformation Monitoring For The Hong Kong International Airport
香港國際機場地面沉降遙感監測 14

Checkered Playhouse
格子屋 15

Air Pollution Decision Support System
空氣污染決策支持系統 16

Touchair - A Real-Time Air Quality App
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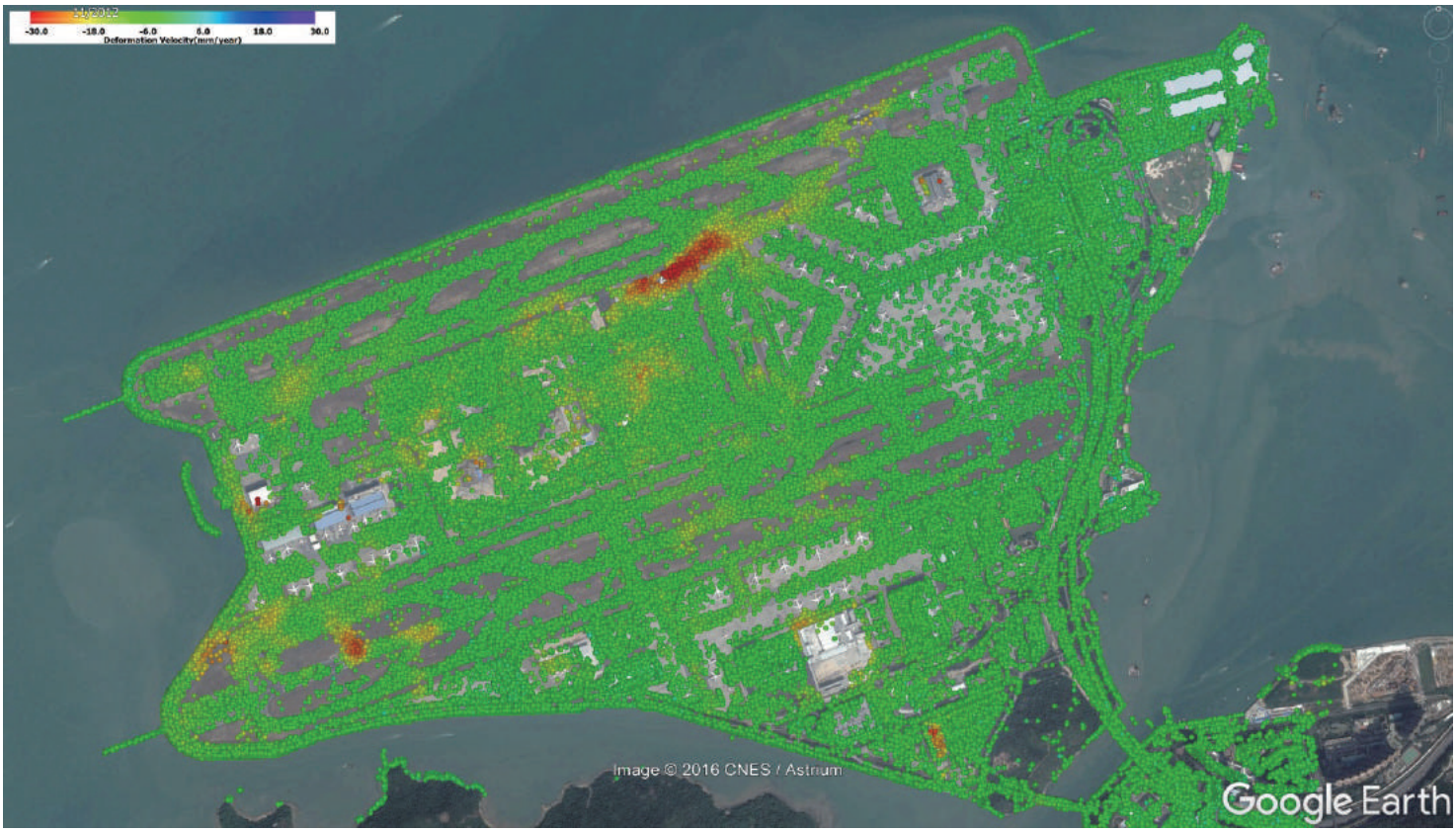
香港國際機場地面沉降遙感監測
USE OF REMOTE SENSING TECHNIQUES IN GROUND DEFORMATION MONITORING FOR THE HONG KONG INTERNATIONAL AIRPORT



Changes in height of the infrastructure at Hong Kong International Airport
香港國際機場建設的高度變化顯示圖

The Hong Kong International Airport (HKIA) is one of the busiest transport hubs, serving over a thousand flights daily. To ensure smooth operations, effective measures are essential for the close monitoring of ground deformation. Traditional measuring methods fail to serve the purpose since huge area is involved and the operation of the airport cannot be disrupted. In view of this, we developed a ground deformation monitoring system using remote-sensing satellite signals, and customize the hardware and software modules with respect to the monitoring workflow of HKIA. With SAR (Synthetic Aperture Radar) tomography, our system provides long term and large-scale deformation monitoring of the infrastructure of the airport, thus maintenance work can be done in a timely manner when necessary.

香港國際機場是全球最繁忙的交通樞紐之一，每天服務過千班航機。要確保運作暢順，我們必須有效監測機場地面的沉降狀況。但機場佔地廣闊，而且時刻在運作，傳統的測量方法未能有效作全面檢查。我們開發了利用遙感衛星信號監測地面形變的系統，並根據機場的監測工作流程特別定制硬件及軟件模組。利用SAR層析成像技術，系統可以在不干擾機場運作的情況下，長期監測整個機場地面以及建築物的形變，從而在適當時進行維護工作。

- Mean settlement velocity as well as time-series settlement will be retrieved monthly using high-resolution (3 m) SAR images
- We propose to integrate persistent scatterer SAR interferometry (PSInSAR), distributed scatterer SAR interferometry (DSInSAR), and small baseline subsets (SBAS) methods for the monitoring of different land types so as to improve the monitoring capability in complex land surfaces
- The system can also be applied in ground subsidence monitoring and urban infrastructure health monitoring in other area of Hong Kong
- 系統每月使用高解析度(3米)SAR圖像檢測平均沉降速度以及時間序列沉降
- 我們提出使用不同SAR信號(永久散射體SAR干涉測量-PSInSAR、分散式散射體SAR干涉測量-DSInSAR和小基線-SBAS)監測不同陸地類型，以改善複雜地表的監測能力
- 本系統可以擴展應用到監測香港不同地區的地面下陷以及基建設施的狀況

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格子屋
CHECKERED PLAYHOUSE

Interior of the first Checkered Playhouse in Gansu (Apr 2015)
第一間格子屋的室內(2015年4月,甘肅)

Checkered Playhouse in Yunnan (Mar 2017)
位於雲南的格子屋(2017年3月)

Easy On-Site Assembling of Checkered Playhouse
格子屋現場組裝過程簡易

Flow Fabrication of Checkered Playhouse in Factory
工廠正在生產格子屋

Checkered Playhouse is a lightweight prefabricated building product developed by The Chinese University of Hong Kong. It is designed with careful thoughts on climate, structure, manufacturing, construction, transportation and maintenance. With its easy-to-assemble feature, persons without professional training or even students can finish the construction within days. The playhouse can be dismantled and reassembled at a different location, or be fully recycled, with no construction waste produced. With great assembling flexibility, the design can easily accustom to different environments and requirements. To date, 58 Checkered Playhouses were built in villages across different provinces including Shenzhen, Shanghai, Beijing, Gansu, Chongqing, Xinjiang.

「格子屋」是香港中文大學團隊發展出的輕型預製建築產品,這一創新設計融合了氣候、結構、製造、建造、運輸、維修等多重考慮。「格子屋」建構過程十分簡易,即使是沒有受過專業訓練的人士,甚至是學生,也可參與建造,並只需數天就能完成組裝。「格子屋」還能被拆除再易地重組,或者完全回收,當中不會產生建築廢料。設計靈活多變,可因應不同環境及使用需求而變化。發展至今已有58幢「格子屋」建成,分佈於深圳、上海、北京、甘肅、重慶、新疆等。

- Characterized with rapid erection, minor foundation works, zero construction waste, re-usability and exquisite spatial experience
- Best suitable for circumstances where houses have to be built within short periods or when heavy machinery is unavailable, e.g. rebuilding work after natural disasters, school building at remote underprivileged rural area
- A green solution to events such as exhibitions where impermanent constructions are needed. All materials can be recollected and reused, hence construction waste can be significantly reduced
- 建造速度快,對場地要求低,不產生現場垃圾,可重復使用,空間效果豐富
- 特別適合需要於短時間內建造、又缺乏大型建築機械的情況,例如災後重建,或於缺乏資源的偏遠農村建學校等
- 可作為展覽等短期活動的環保方案,所有物料可回收再易地重組,大大減少這類型活動所產生的建築廢物

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Collaboration with Unitinno Architectural Technology Development Company Limited
合作夥伴為香港元遠建築科技發展有限公司

空氣污染決策支持系統
AIR POLLUTION DECISION SUPPORT SYSTEM

The monitoring sensors include CO, SO_2, O_3, NO_2, CO_2, temperature, relative humidity, air pressure, and radiation.

傳感器模塊可監測一氧化碳、二氧化硫、臭氧、二氧化氮、二氧化碳、溫度、相對濕度、空氣壓力和輻射等。

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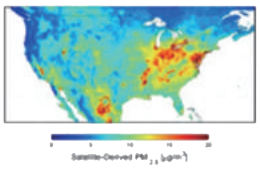
DM ： Date Mining Module (數據挖掘模塊)

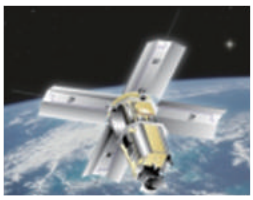
DB ： Database Module (數據庫模塊)

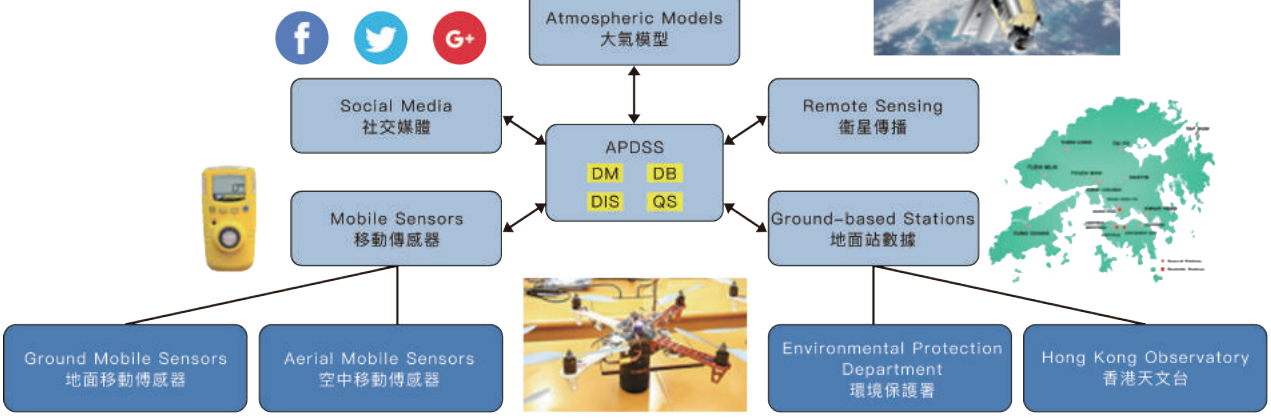
DIS ： Display Module (可視化模塊)

QS ： Query System (查詢模塊)

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{j} = \sigma$$







Air pollution has become a life-threatening hazard that exerts a serious impact on the sustainable development of our cities. The measurements from stationary ground-based stations are relatively costly and they are generally too sparse to build a complete and accurate picture of air pollution.

We have developed an Air Pollution Decision Support System (APDSS) that puts together all relevant multi-scale and multi-source data for the investigation of and decision-making on urban air pollution. We have also developed a compact Modular Sensor System with expandable plug-and-play sensor modules and multiple Wireless Sensor Networks compatibility.

空氣污染對人類生命構成威脅，更對城市的可持續發展產生嚴重影響。固定的地面空氣監測站的成本相對昂貴，且分佈稀疏，無法建立整全和準確的空氣污染圖像。

未來城市研究所開發空氣污染決策支援系統(APDSS)，整合不同規模、不同來源的相關數據，以促進有關城市空氣污染的調查和決策。我們還開發了一個簡潔的模塊化傳感器系統，系統具有可擴展的即插即用傳感器模塊，並兼容多個無線傳感器網絡。

- APDSS is the first system to amass and integrate multiple sources of air pollution data in Hong Kong
- Our specially designed sensor node allows measurement of multiple pollution and weather variables at the same time
- The modularized sensors are equipped with configurable sensing capability, Plug-and-Play function, and support multiple wireless communication links
- Depending on different needs, the Modular Sensor System can be made wearable, stationary or vehicular
- The system is applied to the Community Weather Information Network (CoWIN) jointly hosted by IOFC, Hong Kong Observatory and Hong Kong Polytechnic University with over 100 secondary schools, collecting various kind of weather information in the community
- APDSS是首個在香港積累和整合多個空氣污染數據來源的系統
- 特別設計的傳感器節點能夠同時測量多種污染物和天氣變化
- 模塊化傳感器具有可調整的傳感配置和即插即用功能，並支持多種無線通信
- 因應需要，模塊化傳感器可以穿戴、固定放置或設置在車輛上
- 此系統現應用於由未來城市研究所、香港天文台和香港理工大學合辦的社區天氣信息網絡(CoWIN)，有超過100所中學參與，一同收集和分享區內的各種天氣信息

「點藍空氣」- 即時空氣污染監測手機應用程式
TOUCHAIR - A REAL-TIME AIR QUALITY APP

一個可計算香港和中國任何地點實時污染物濃度的估算模型
A statistical model for the estimation of air pollutant concentrations in real time at any locations in Hong Kong and mainland China

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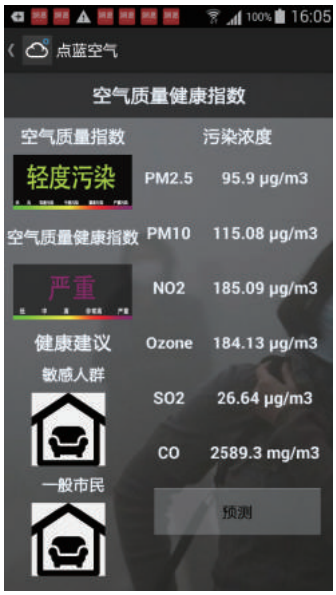

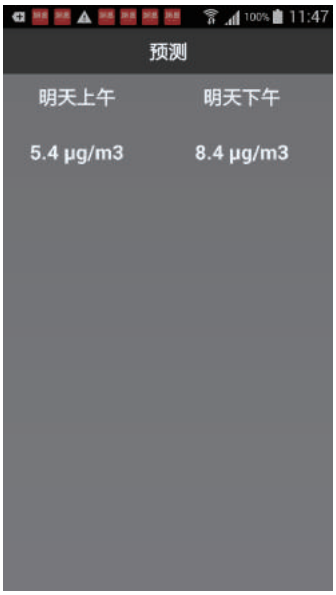

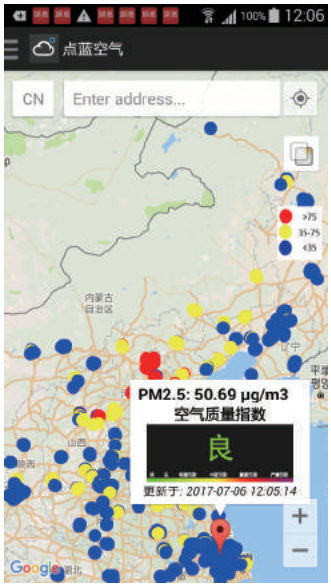

Hong Kong and other cities in China are suffering from serious air pollution problems. Public awareness of ambient air quality has been growing since poor air quality can cause serious health problems. Monitoring of air quality is probably a starting yet crucial step to mitigating air pollution. However, due to high operation cost, ground monitoring stations are usually limited and sparsely distributed, rendering them insufficient to capture large spatial variation of air quality over a city.

In this project, we have devised a spatio-temporal statistical model that utilizes MODIS data, AERONET data and meteorological parameters to improve the estimation accuracy. By using this new method, people can access real-time air pollutant concentrations, including PM2.5, PM10, NO_2, Ozone, SO_2 and CO, with higher accuracy at any locations.

近年，香港和中國城市受到異常嚴峻的空氣污染考驗。由於空氣污染可危害健康，大眾對空氣污染問題日益關注。準確監測空氣污染物濃度是對付空氣污染的先決條件，但基於土地、儀器、人力成本的各方面因素考慮，城市地面空氣監測站點數目有限，而且分佈稀疏，無法提供覆蓋整個城市所有地方的空氣污染物變化數據。

我們開發了一個基於即時空氣監測資料、氣象資料以及遙感影像資料的空氣污染物濃度估算模型，讓用戶可以更準確地獲得任何地點的實時污染物濃度，包括PM2.5、PM10、二氧化氮、臭氧、二氧化硫和一氧化碳等。

- The model provides estimation and visualization of air pollutant concentrations in real time at any locations in Hong Kong and mainland China
- A Smartphone App, TouchAir, has been developed for real time air pollution information access; routing planning for outdoor activities; and public health correlational studies
- The App can also predict PM2.5 concentrations in 24 hours

- 模型可估算並以圖像展示香港及中國大陸任何地點的實時污染物濃度
- 我們開發了「點藍空氣」手機應用程式，讓用戶隨時獲取空氣污染資訊，並根據指數計劃戶外活動的行程。另外，程式亦支持空氣污染和公眾健康的關連性研究
- 程式同時提供PM2.5濃度的24小時預測

INFORMATION & COMMUNICATION TECHNOLOGIES
信息和通訊科技

Easy-To-Setup Wireless Smart Counter Assignment System
簡易安裝的無線智能服務櫃位分配系統 20

Cloud-Based Smart Service Queue Management System
雲端智能服務輪候管理系統 21

Deep Extraction Of Manga Structural Lines
利用深度神經網絡提取漫畫結構線 22

Efficient Mapping Algorithms For 360-Degree Videos
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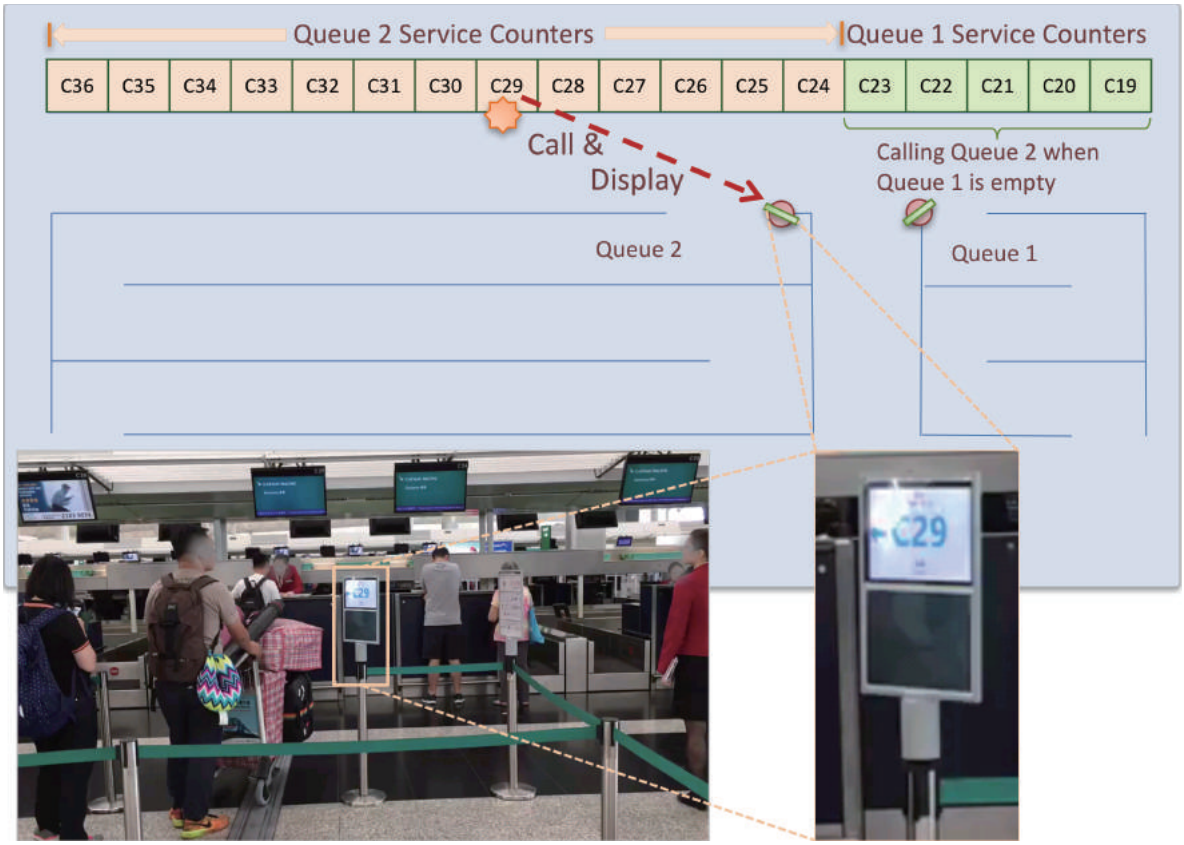
ACT - Automatic Chinese Typo Detection System
中文錯字和粵語檢測系統 24

Virtual Campus System
虛擬校園系統 25

簡易安裝的無線智能服務櫃位分配系統
EASY-TO-SETUP WIRELESS SMART COUNTER ASSIGNMENT SYSTEM

彈性配合臨時排隊設置以促進服務櫃位的運作
Flexible System for facilitating service counter operations with ad-hoc queue setting



Our easy-to-setup Counter Assignment System is designed to fit different queue settings and even cross-queue operational needs.
我們設計的服務櫃位分配系統，能夠配合不同的排隊設置甚至跨隊列運作需求。

At occasions such as arts/sports/entertainment festivals, exhibitions, or at transit hubs such as airports, service counters often need to be set up for registration, admission or other services. The number and configuration of the service counters have to be adjusted according to the venue, time periods and the needs of different service providers. Commercially available counter assignment systems require equipment installation process commonly supported by relevant building and cabling infrastructure, hence lack the flexibility to serve the ad-hoc nature of the above circumstances.

With a specially designed wireless communication mechanism, our novel counter assignment system can flexibly meet the different operation requirements in all different occasions.

於人流多的場所，例如藝術、體育、娛樂活動場地、大型展覽、或機場等交通樞紐，很多時需設置櫃位以作登記、入場或其他服務之用。服務櫃位的數量和設置需按場合、時段以及不同供應商的要求而改變。市場上的服務櫃位分配系統，需因應固有的建築、電纜等結構去安裝，缺乏彈性，未能應付以上場合臨時且多變的要求。

我們設計的服務櫃位分配系統，使用特別設計的無線傳輸技術，可彈性配合不同場合的運作需求。

- Portable, can be set up easily and quickly, flexible
- No network or power cabling
- Specially designed wireless communication mechanism eliminates interference by other wireless communication signals in the same venue
- Can link different set of service counters as needed, and support cross-queue operations
- Easy to configure relative directional signals based on ad-hoc queue exit
- 便攜、安裝快速簡單、使用彈性高
- 毋需網絡線或電線
- 特別設計的無線傳輸技術，能確保訊號不會受現場大量的外來無線訊號干擾
- 能因應需要連接不同組別的服務櫃位，並支援跨隊列運作
- 容易因應臨場排隊出口位置改變即時調整方向指示

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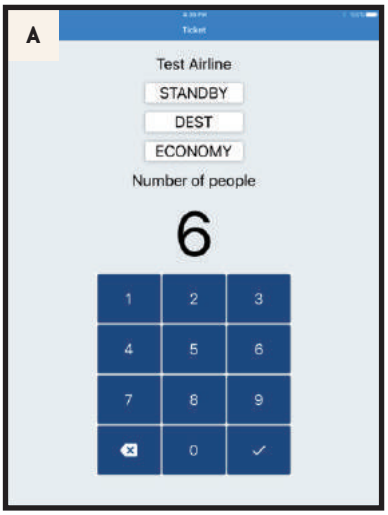
Collaboration with Hong Kong International Airport and Hong Kong R&D Centre for Logistics and Supply Chain Management Enabling Technologies
合作夥伴包括香港國際機場及香港物流及供應鏈管理應用技術研發中心

雲端智能服務輪候管理系統
CLOUD-BASED SMART SERVICE QUEUE MANAGEMENT SYSTEM

在突發情況下有效地安排資源以服務顧客的即時需求
Facilitate real-time resource planning for servicing near-term customer needs under ad-hoc circumstances



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A Request for Service
輸入要求之服務

B Ready for Issuance
準備列印

C iPad mini with Portable Thermal Ticket Printer
iPad mini及可攜式熱感票券打印機

D Request handling progress being shown and informed to corresponding queue ticket holders
持票人可收取通知並檢視服務處理進度

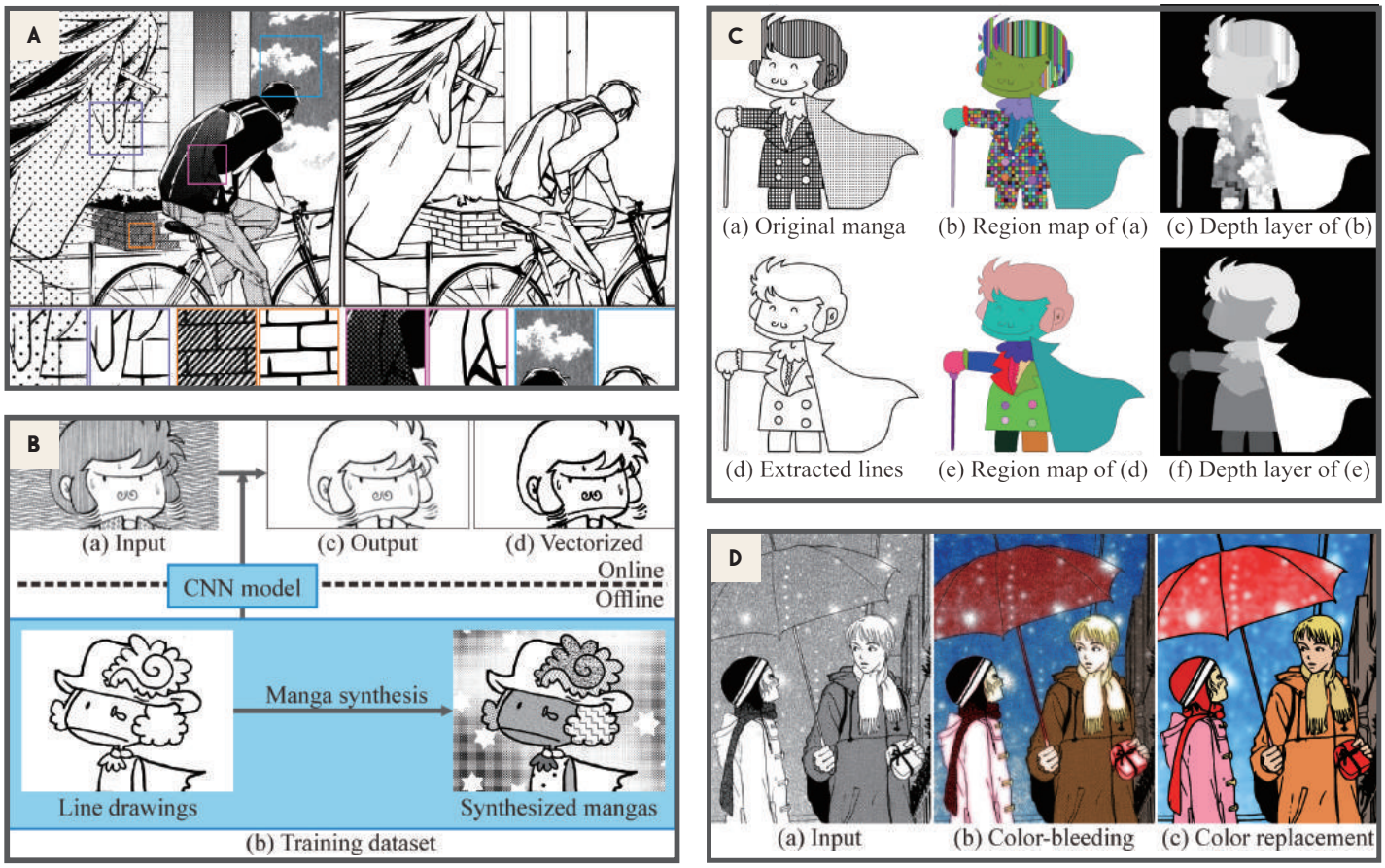
In transit hubs such as airports, flights are sometimes delayed due to unexpected weather or other incidents. Distressed passengers may change their needs that require corresponding service providers to re-allocate resources to meet all different demands. To support the urgent management of such chaos, we designed a customizable queue ticket management system which can be easily set up for collecting updated requests from customers for service providers to make collective plans to accommodate all the needs.

機場等交通樞紐的運作時常會受到天氣或意外影響，以致未能如期提供原定航班服務。服務供應商需即時重新分配資源，以應付受影響乘客臨時更改的服務要求。為有效管理這類緊急情況，我們設計出可因應指定需求設定而且容易安裝的服務輪候管理系統，讓服務供應商可收集並整合顧客的最新要求，從而作出周全的安排以滿足各方面的所需。

- Cloud-based data allows customers at different locations to queue for the same designated service. This helps to avoid assembling too many customers at a single place at the same time
- Portable, wireless, and easy-to-setup
- Support multi-level administrative and operational handling of multiple queues
- Continuously keep customers informed about the processes in real time and communicate with them in organized manner
- 需端數據讓身在不同地點的顧客可以依次輪候同一指定的服務，這功能可避免了顧客湧往現場輪候的擠擁情況
- 便携式、無線、容易安裝
- 支援多隊列的多層面管理及運作
- 有系統地與顧客溝通，持續為他們提供最新資訊

利用深度神經網絡提取漫畫結構線
DEEP EXTRACTION OF MANGA STRUCTURAL LINES

自動從背景中將主要結構線提取出來，從而促進漫畫電子化
Facilitate manga digital migration by automatically extracting structural lines from patterns



A Extracted structural lines from a manga image using our method
漫畫結構線提取結果

B System framework
系統框架

C Application: manga depth reconstruction
應用：漫畫深度信息重建

D Application: manga colorization
應用：漫畫上色

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With the wide popularity of portable devices and the low-cost distribution over the internet, there has been an increasing trend to convert legacy manga to digital form. Comparing to traditional paper-based manga, electronic manga or e-manga is more visually appealing as more visual elements, such as color presentation and powerpoint-like animation, can be easily introduced. During digital migration, extraction of structural lines from pattern-rich manga is a crucial step. Unfortunately, it is very challenging to distinguish structural lines from arbitrary, highly-structured, and black-and-white screen patterns. In this project, we present a novel data-driven approach to identify structural lines out of pattern-rich manga based on convolutional neural networks. Our method can benefit the manga industry in migrating legacy manga to digital manga, which includes a large set of manga-related applications, e.g. manga colorization, manga vectorization, manga retargeting, stereoscopic manga conversion, etc.

隨著移動設備和網絡的普及，愈來愈多漫畫公司開始將現有的紙版漫畫轉為電子漫畫。電子漫畫在視覺上比紙版漫畫更為吸引，色彩顯示更豐富，又可加入簡單的動畫。提取漫畫中的結構線是電子化過程的關鍵步驟。但是要從任意、複雜且黑白的背景圖案中將結構線識別出來，是十分困難的。為了解決這個問題，我們提出了一個基於深度神經網絡的漫畫結構線提取算法，可以從漫畫的豐富圖案中有效提取結構線。這個技術可以廣泛應用於漫畫電子化之中，包括漫畫上色、漫畫矢量化、漫畫立體化等。

- Our method outputs clear and smooth structural lines regardless of their scales or their positions relevant to the patterns, or even if these lines are contaminated by and immersed in complex patterns, such as irregular, tone-varying, or even pictorial patterns
- By learning high-level semantics of manga images with the help of convolutional neural networks, our method can extract clear and smooth structural lines from manga images with arbitrary screen patterns
- Our method substantially outperforms other state-of-the-art methods in terms of visual quality extraction efficiency
- 不論結構線在背景圖案中的位置和大小，也不論背景圖案是不規則的、漸變的、甚至是圖片形式的，我們都可從中提取清晰平滑的結構線
- 藉助深度學習網絡，我們的方法可以通過學習漫畫圖片的高層次語義從而提取出清晰平滑的結構線
- 我們的方法的提取效果和提取效率都遠超過現有的其它算法

360度全景視頻高效投映演算法
EFFICIENT MAPPING ALGORITHMS FOR 360-DEGREE VIDEOS

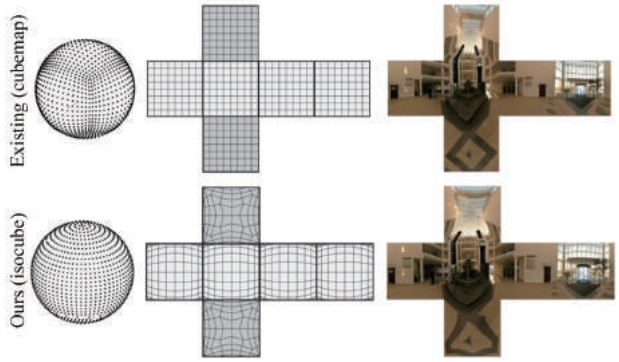
提高360度視頻的圖像質量與投影效率的映射方案
Mapping solutions for enhancing the quality and the efficiency of 360-degree video

360-degree video frame
360度視頻幀

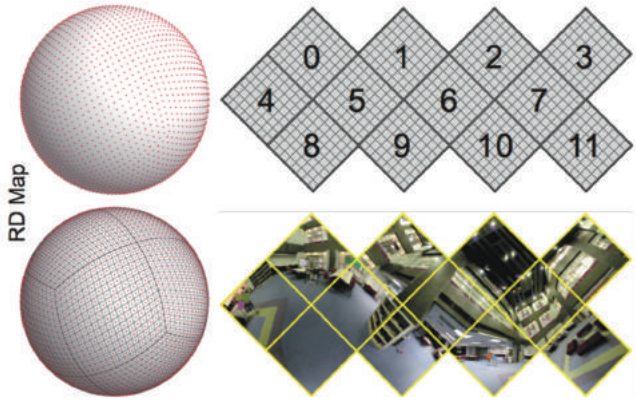
360-degree cameras
360度攝像設備

Recently, Virtual Reality (VR) has become the basis of the future I.T. industry. Different from flat displays that display flat videos, VR devices are able to display 360-degree scenes that are more close to human vision. To display VR videos (or 360-degree videos), spherical mapping is usually used to display the stored data in a 360-degree view. However, classic spherical mapping is inefficient in generating high-quality (e.g. 2k/4k image resolution) 360-degree images/videos. Blurry artifacts are quite common when the images/videos are played on high-resolution displays. To efficiently store and map 360-degree images/videos with high quality, we propose several novel mapping schemes to enhance the quality and the efficiency of 360-degree video mapping, including fast isocube (novel six-face) spherical mapping, rhombic dodecahedron mapping, unicube spherical mapping for dynamic environment mapping, and HEALPix spherical mapping.

近年，以虛擬現實（VR）體驗為核心的浸入式媒體成為了下一代IT產業發展的基礎。有別於普通的顯示設備，VR設備可以展示360度影像，更貼近人類的自然視覺。然而，VR設備使用的360度視頻所必須的球面影像，卻缺乏一種有效的編碼和投映方案。在2k或4k等高清圖像質量需求下，龐大的計算負擔已成為最大的瓶頸之一，當影像在高清螢幕上顯示，就會出現失真的情況。為了提高360度視頻的圖像質量與投映效率，我們提出多個新穎的360度視頻的投映方案，包括快速等立方體球面投映、菱形十二面體投映、Unicube動態環境投映、HEALPix球面投映等。



Comparison between existing cubemap and our proposed isocube
對比現有的球面映射和我們提出的快速等立方體球面映射



Rhombic dodecahedron mapping
菱形十二面體映射

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由香港研究資助局資助

- Our method can benefit anything that involves spherical mapping and playback, which is a key feature in 360–degree video streaming, VR networking and digital entertainment
- Our mapping schemes can be applied directly to all existing VR videos/360–degree videos on existing hardware platforms without requiring any further effort to build new hardware platforms i.e. no extra cost
- Our methods can greatly improve the visual quality of the mapped 360–degree images/videos while remaining efficient. Our method achieves the maximum efficiency with GPUs while maintaining high fidelity and dynamic effects
- 我們的方法可以用於任何需要球面投映的應用當中，其中包括360度視頻顯示、VR設備與相關技術、以及數字娛樂產業的其它相關技術等
- 我們的新方案可以直接應用於現有的硬體框架，不需要新硬體或搭建新的系統框架，沒有額外成本
- 我們提出針對360度視頻編碼和球面投映的新方案，可以保持高效率運行同時大幅提升視頻顯示的清晰度，並在GPU的幫助下達至最高運行效率

中文錯字和粵語檢測系統
ACT - AUTOMATIC CHINESE TYPO DETECTION SYSTEM

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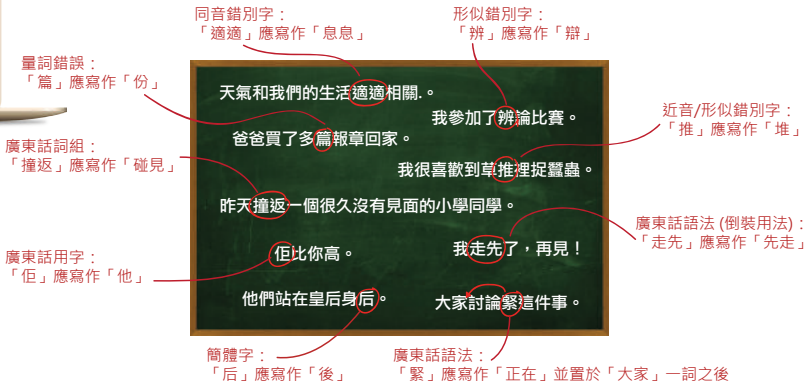
The system will automatically detect the errors and offer replacement suggestions of the input sentences.

系統會自動在輸入的句子中標示出錯誤的地方並提供修正建議



Colloquial expressions, abbreviations and slang are integrated into daily language for teenagers. Such behavior may lower the Chinese language writing proficiency of many students. In view of the problem, CUHK developed an error detection system called ACT, which is based on Big Data Mining and Deep Learning, and in conjunction with a unique intelligent algorithm and a novel scoring mechanism. ACT is the first of its kind in Hong Kong and targets local students. It took just a few seconds to analyze an article with thousand of words. For every detected error, ACT will also try to offer replacement suggestions.

隨著社交網絡及即時通訊軟件興起，年青人習慣使用各式各樣的口語、縮寫、諧音，甚至同時以中英語夾雜符號與人溝通，部分學生的中文書寫水平因而受到影響。有見及此，中大透過大規模「粵語數據挖掘」及「深度學習」，並配合獨特的「智慧演算法」和新穎的「評分機制」，研發了一個名為ACT的中文錯字和粵語檢測系統。它是全港首個為本地學生量身打造的自動中文檢測系統。ACT只需要數秒鐘的時間便可以完成分析一篇過千字的文章。對於每一個檢測到的錯誤，ACT 亦會嘗試提供替代的建議。

- Large amount of articles can be processed in a short time with a low error rate
- Scores are assigned to potential corrections based on big data mining, deep learning, and a unique intelligent algorithm so that users are always offered the most suitable replacements
- Database is continuously expanding and being optimized through big data mining and deep learning
- 可快速分析大量文章，而誤報率也極低
- 系統透過大數據挖掘、深度學習及獨特的智慧演算法為不同修正建議作出評分，從而提議最合適的改正方法
- 數據庫可透過大數據挖掘和深度學習技術不斷擴充及優化

虛擬校園系統
VIRTUAL CAMPUS SYSTEM

作為發展智慧校園基礎的全新互動媒介
A novel communication medium that serves as a platform for developing smart campus

360-degree video frame
360度視頻幀

Users can interact with each other as avatars in the virtual campus

用戶可以化身為「阿凡達」於虛擬校園跟其他用戶互動

We have developed a virtual campus system and have constructed the virtual campus of The Chinese University of Hong Kong (CUHK) based on the real scenery. Exploring the virtual 3D world as avatars, users can not only learn about the architectural, cultural and natural environment of CUHK, but also interact with other users. Dynamic environmental factors are merged into the 3D campus model, allowing users to experience the seemingly real CUHK campus from all locations. This novel communication medium serves as a platform for developing smart campus by providing a comprehensive social experience at scales from personal activities to socio-spatial practices for teachers, students, alumni as well as the public.

我們開發了一個虛擬校園系統，並根據香港中文大學(中大)的真實場景建構出中大虛擬校園。用戶可以化身為「阿凡達」，進入三維虛擬世界全面探索中大的建設、人文環境與自然景觀，並與其他用戶交流互動。虛擬校園根據中大的真實場景構建，並融入動態的環境數據，讓置身於各個地方的校友，猶如親臨其境。這個全新的互動媒介讓師生、校友以至大眾可於虛擬校園裡參與個人及群體活動，為發展智慧校園提供了一個重要的基礎。

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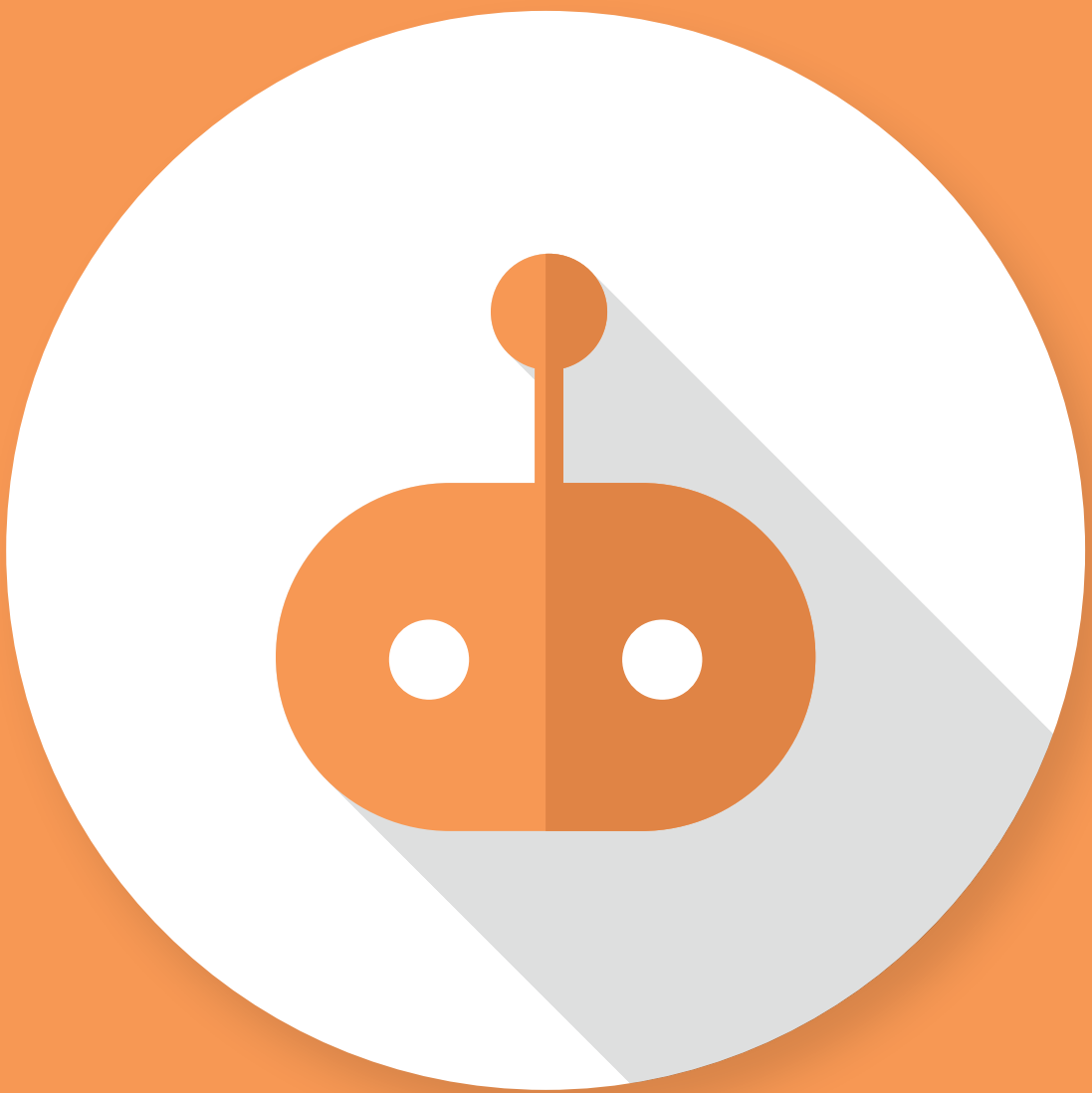
Collaboration with Peking University
合作夥伴為北京大學

Our method can benefit anything that involves spherical mapping. The system is developed with three levels:

- Opensim–based collaborative geographical scene construction
- Merging dynamic environmental factors that are relevant to our everyday life e.g. day/night time, seasons
- Providing an immersive fusional experience for users' interaction, communication and social activities

虛擬系統分為三個層次:

- 以OpenSim綜合多源數據建構三維場景
- 融合與日常生活有關的動態環境數據，例如日夜、季節等
- 提供交互式的沉浸式體驗，讓用戶互動、通訊、進行社交活動



ROBOTICS & AUTOMATION
機械人及自動化技術

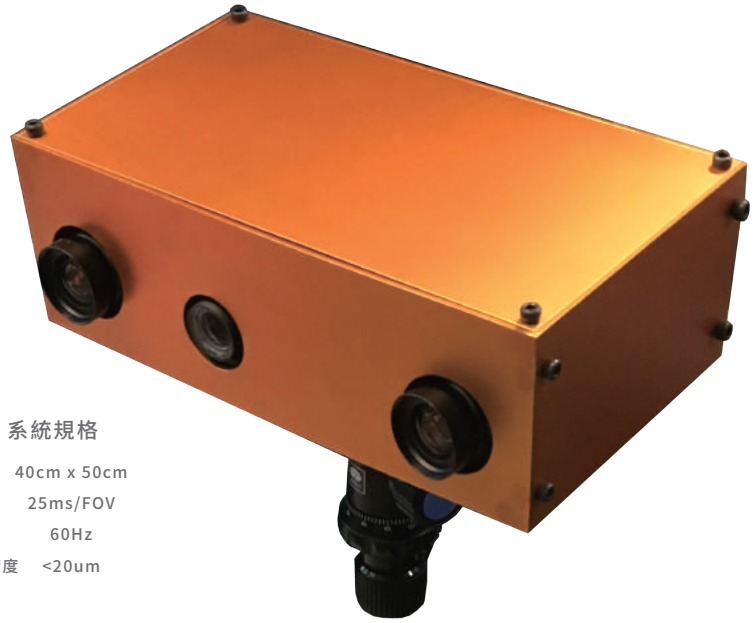
High-Speed And High-Resolution 3D Imaging System
高速高清三維成像系統 28

Structural Coloration of Metals
金屬結構上色 29

Levitation Actuator Using Near-Field Acoustic
近場聲學懸浮驅動器 30

XL-Laser: Extra Large 3D Cable-Driven Laser Cutting Robot
大空間 3D 線驅動激光切割機械人 31

高速高清三維成像系統
HIGH-SPEED AND HIGH-RESOLUTION 3D IMAGING SYSTEM



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System Specifications 系統規格

Field of View 視場	40cm x 50cm
Capture Speed 採集速度	25ms/FOV
3D Imaging Rate 3D成像採幀率	60Hz
Measurement Accuracy 測量精度	<20um

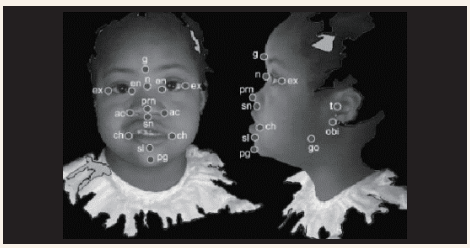
3D scanning technology is widely used in a lot of different areas, such as medical applications, fitness tracking, apparel design, human systems engineering, etc. However, existing 3D imaging systems are still incompetent to capture high resolution 3D images at high speed. Therefore, we propose a high-speed and high-resolution 3D imaging system by integrating: 1. a novel stereo photogrammetry algorithm and 2. FPGA-based parallel image capturing and processing technology.

三維掃描系統廣範地應用於各個範疇，包括醫學、健康追蹤、服裝製造以及人體工程等。但現時的三維成像系統仍受技術所限，未能高速地獲取高精度的三維影像。因此，我們結合以下兩項特點，研發出高速高清三維成像系統：1. 先進的立體成像演算法；2. FPGA的並行圖像採集及處理技術。

- Novel patentable technologies
- High speed
- High precision
- Low cost

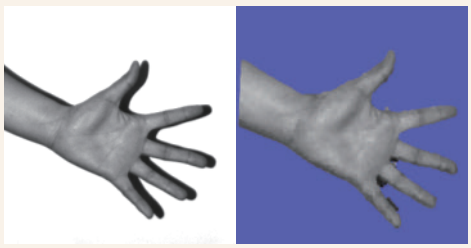
- 新型專利技術
- 高速
- 高精度
- 低成本

Applications 應用



Doctors can make precise measurements of facial features within seconds, and illustrate to patients the reconstruction results of the surgical procedure.

醫生可於數秒鐘內準確量度所有面部特徵，並展示整形的手術效果。



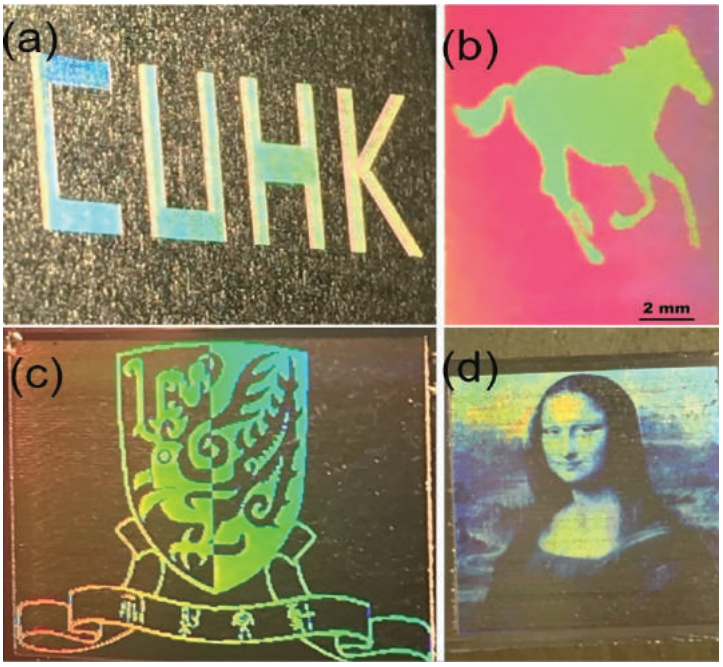
Precise 3D data help users to compare their body' s shape, pose and motion etc. on daily basis. Records of the fine changes in body will help design fitness / rehabilitation plans.
準確的三維數據讓用戶可以每天比較體型、姿態和動作的變化，仔細的變化紀錄有助他們製訂健身/康復計劃。

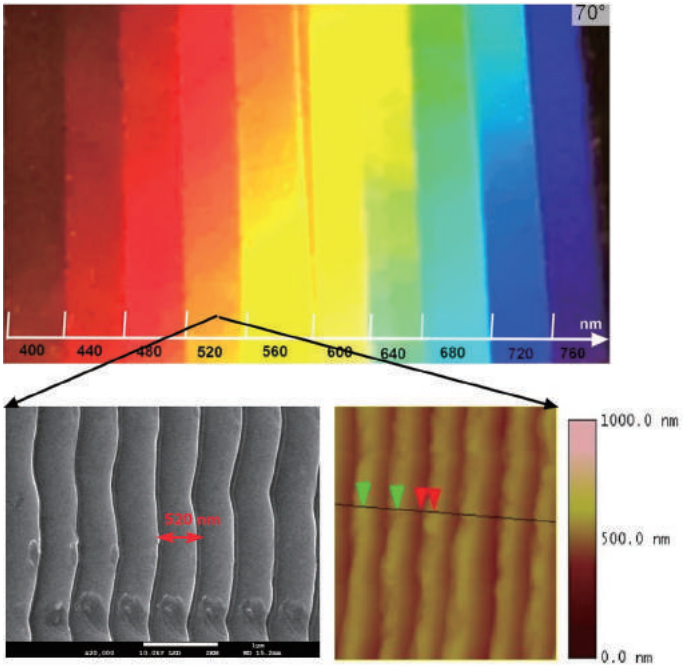
The 3D scanner allows instant analysis of the size and orientation of the objects on the assembly line. The corresponding robot arm can then act accordingly e.g. pick up / reposition / remove the object.

三維掃瞄讓系統可以即時分析運輸帶上物件的大小和方位，從而讓機械臂可以作出相應動作，例如抓起、重置或移除物件。

金屬結構上色
STRUCTURAL COLORATION OF METALS

利用超聲橢圓振動切割加工技術以低成本生產彩色金屬結構
Cost-effective structural coloration of metals through ultrasonic elliptical vibration texturing (EVT) technology



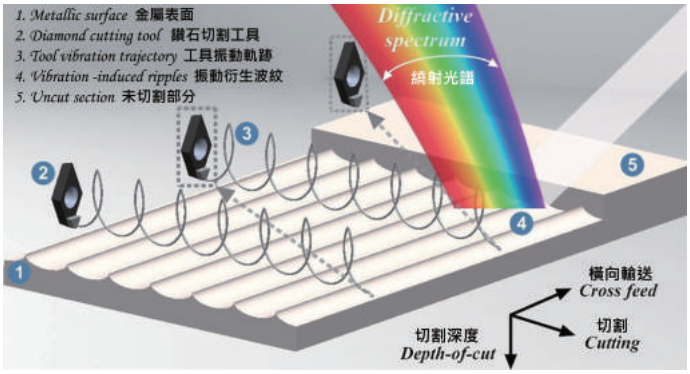


Optically variable colorful images produced with ultrasonic EVT technology
以超聲振動切割加工技術生產的光學變色圖案

Gratings have a rainbow-like iridescent effect because its micro/nano structure reflects different lights at different viewing angles. With this phenomenon, we can produce arbitrary optically variable colorful images by adding grating structure on metal surface. Such technology can be employed in anti-counterfeiting and jewelry design etc. Commercial market usually adopts ultrafast laser ablation method to fabricate metal molds for compression molding, which is highly expensive and a new mold will be required for each design. Our ultrasonic EVT technology enables concurrent production of a series of precise and controllable micro/nano grating structures at an economical cost.

光柵擁有像彩虹顏色的結構色，是因為其微納米結構會隨著不同觀測角度反射不同顏色的光。基於這個原理，我們可以將光柵加工在金屬表面，從而生產擁有光學變色效果的圖像。這類技術可應用於製造防偽標簽，以及首飾加工等。目前市場上多採用超快雷射脈衝腐蝕技術去生產壓印金屬模具，成本昂貴，而且每個模具只可製作一款圖像。我們研發的超聲振動切割加工技術，能以低成本一次過生產一系列精確且可調控的微米/納米光柵結構。

- Cost-friendly as no ultrafast laser system is involved
- Highly-efficient creation of full pallet structural colors
- Precise control of grating profiles and distribution
- Production of arbitrary optically variable colorful images using structural coloration
- 毋須任何高速鐳射系統，大大降低成本
- 可高效生產具有所有顏色的結構色
- 可精確控制光柵結構的形貌和表面分佈
- 可生產具有光學可變效果的任意結構色圖案



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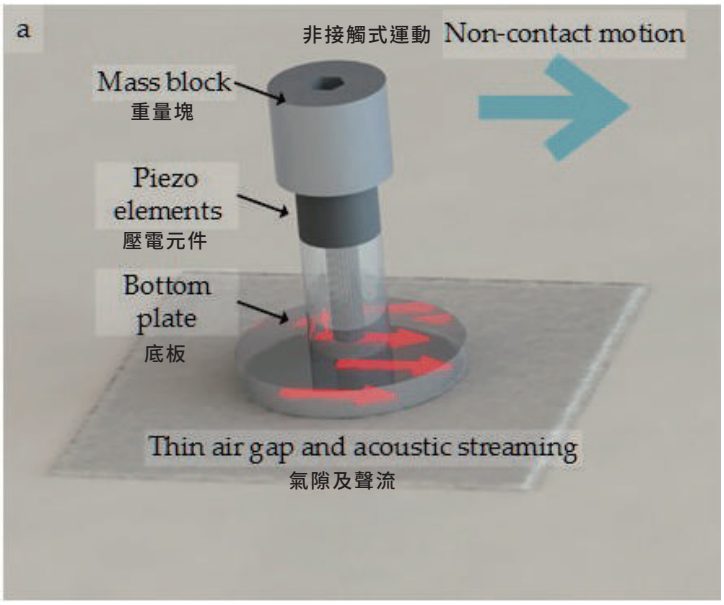
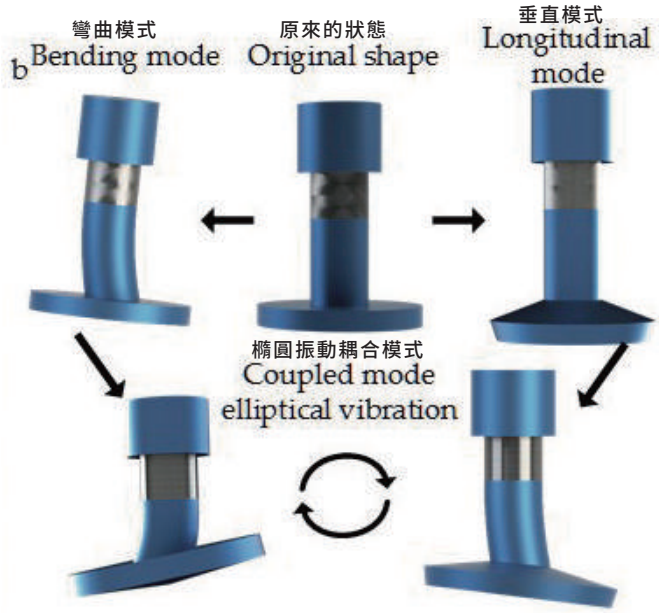
由創新科技署資助

近場聲學懸浮驅動器
LEVITATING ACTUATOR USING NEAR-FIELD ACOUSTIC

可跟隨指定二維軌跡活動的自推進、自懸浮驅動器
A self-running and self-floating actuator for non-contact motion in designated two-dimensional directions



Components of self-floating actuator
自懸浮驅動器的組成



Operation of self-floating actuator
自懸浮驅動器的運作

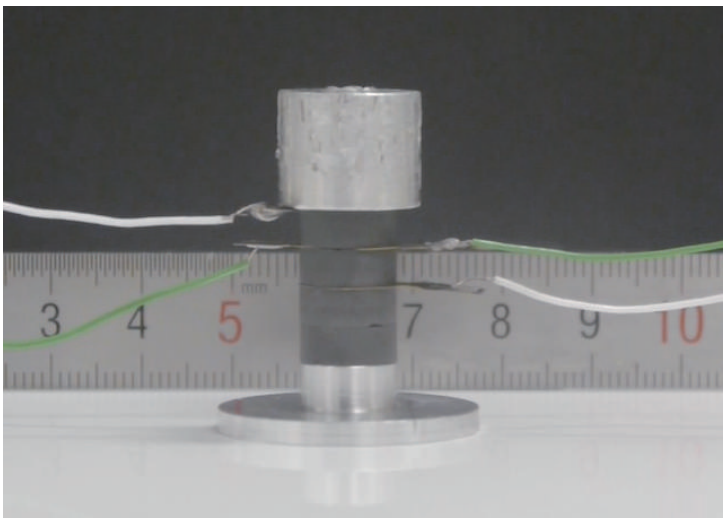
Non-contact actuators, such as air bearings and magnetic levitation bearings, are widely employed in precision machine-tools, nanotechnology, and metrology for their high precision, low noise, negligible friction and wear. However, these actuators have their drawbacks such as complex design, high costs, constrained moving ranges, electromagnetic interference, undesirable noise, requirement of clean air, etc.

Acoustic radiation force in the near-field of a vibrating source can be utilized to lift and transport objects, which provides a non-contact driving technology in addition to magnetic levitation. This project focuses on a novel self-running and self-floating planar motion stage capable of two-dimensional motion with an unlimited travel range. The proposed design exploits near-field acoustic levitation for object lifting, and coupled resonant vibration for generation of acoustic streaming for non-contact motion in designated directions.

使用氣浮軸承和磁懸浮軸承等非接觸式驅動器，其好處包括高精度、低噪音、無摩擦磨損等，因而被廣泛應用於精密機床、納米級驅動與精密測量等領域。但這些驅動器有其局限性，例如複雜的設計、高昂的成本、有限的施工範圍、電磁干擾、噪音以及對潔淨氣源的需求等。

振動源在近場中產生的輻射力，可以用來提升和運輸物件，是磁懸浮技術以外的另一種非接觸式驅動技術。本研究提出了一種新型的自驅動、自懸浮平面運動機構，能夠在二維方向無限距離走動，該機構利用了近場聲學傳播現象來提升物件，並利用耦合諧振帶動物件往指定方向前進。

- Simple design, low cost, low power
- Unlimited moving range, no electromagnetic interference, noiseless
- Can follow the instructed trajectory with a high frequency response
- Applications may include: non-contact type flaw detection for workpiece; laser processing with large dimension scale; non-contact material transportation on high-cleanliness and fragile surface etc.
- 結構簡單、成本低、耗電量低
- 無施工範圍限制、無電磁干擾、無噪音
- 頻響的反應速度快，能快速跟從指示改變行走軌跡
- 可應用於工件表面的非接觸式探傷與檢測、大尺度範圍的表面激光加工、高潔淨度或敏感工件表面上的非接觸式物料運輸等



Prototype of the self-floating and self-running actuator
自推進與自懸浮驅動器的原型

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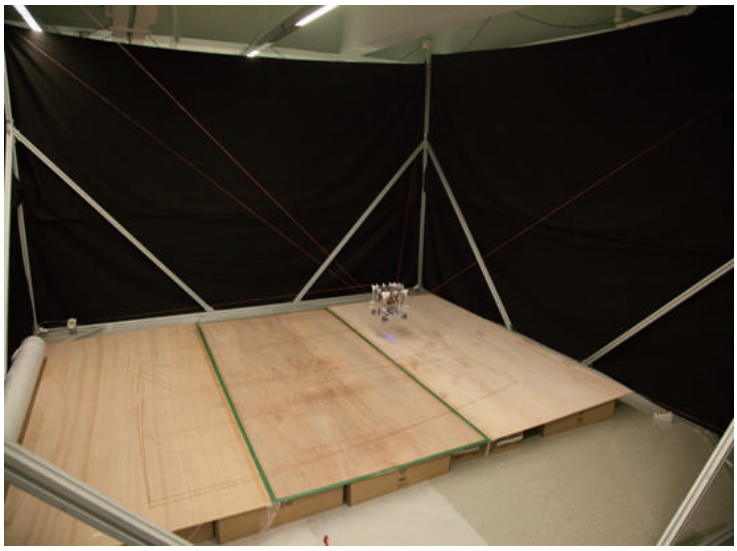
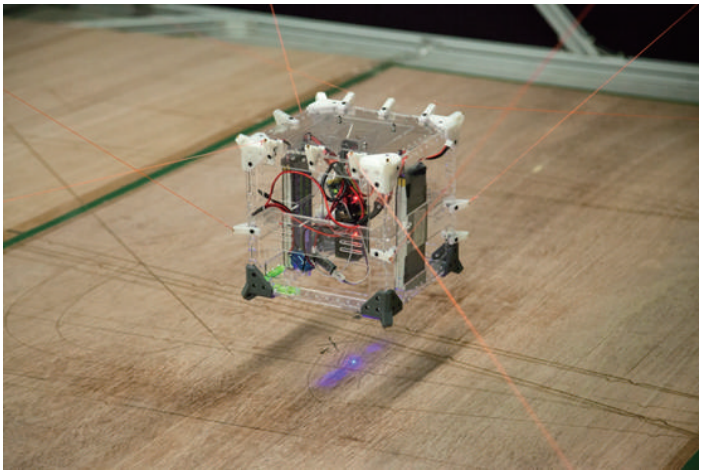
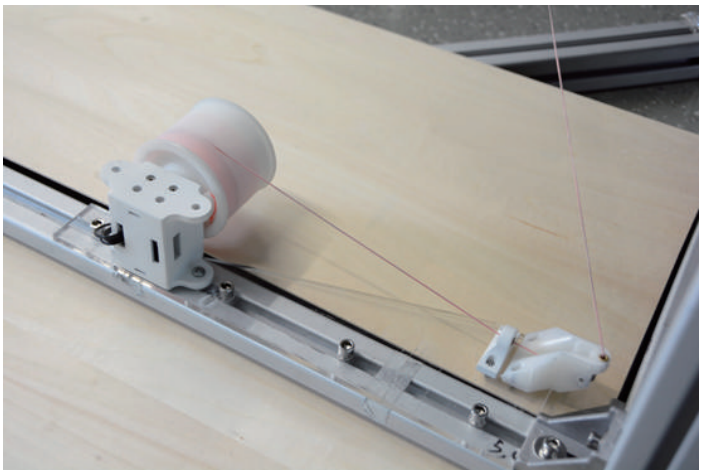
大空間 3D 線驅動激光切割機械人
XL-LASER: EXTRA LARGE 3D CABLE-DRIVEN LASER CUTTING ROBOT



XL-Laser system
XL-Laser系統



Laser end-effector (connected by 8 cables)
激光頭 (連繫8條纜線)



XL-Laser cable actuator with 4m cable
XL-Laser的綫驅馬達(線長四米)

Machines used in rapid prototyping and light industry, such as 3D printing, cutting and engraving, typically operate in a smaller volume or area. This is due to the significant increase in complexity, weight and cost of larger systems, owing to the rigid links and actuation methods that are currently used. A laser cutter which operates only in one squaremeter costs several hundred thousand Hong Kong dollars; while it can only operate on a single planar surface.

Our team has developed a cable-driven large-scale laser engraving and cutting robot that breaks through the above limitations. To achieve a light-weight, portable and large cutting area, the laser end-effector is moved through a set of cables connected to it in parallel. The developed 4m x 4m x 4m system shows its simplicity and expandability, where the cable actuators and end-effector can be deployed easily at different locations and with little limitation to its maximum size.

現時一般用於快速成型和輕工業的機械，如3D打印、切割和雕刻技術，通常限制在一個較小的空間或平面運行。由於系統的複雜性、重量和成本會隨著系統的規模而顯著增加，要製作較大型的製成品往往十分困難。現時市面上切割面積不足一平方米的激光切割機價值達數十萬港元，而它們更只能在平面上進行切割。

中大團隊開發的大型激光雕刻切割纜索機械人能突破以上限制。我們透過控制綫長，操控在端部執行器上安裝了激光模組之纜索機械人的移動，從而控制激光行走的軌迹，實現輕型、便攜和大型切割範圍的效果。現時的4米 x 4米 x 4米系統不但簡潔，更具擴展能力，纜索電機和端部執行器可以容易在不同位置安裝，提高纜索機械的可塑性，打破一般激光切割機械的規模限制以及增加同一系統的應用。

- Very large operational volume
- Simple design and low cost
- Portable and easy to setup at any location
- Ability to operate in 3D
- Ability to replace the end-effector for different lasers or even other tools

- 極大的運行空間和規模
- 成本低及架構簡潔
- 便於在任何空間安裝設置
- 能夠在立體空間運行和雕刻切割
- 能夠在末端執行器更換不同激光模組以及其他工具

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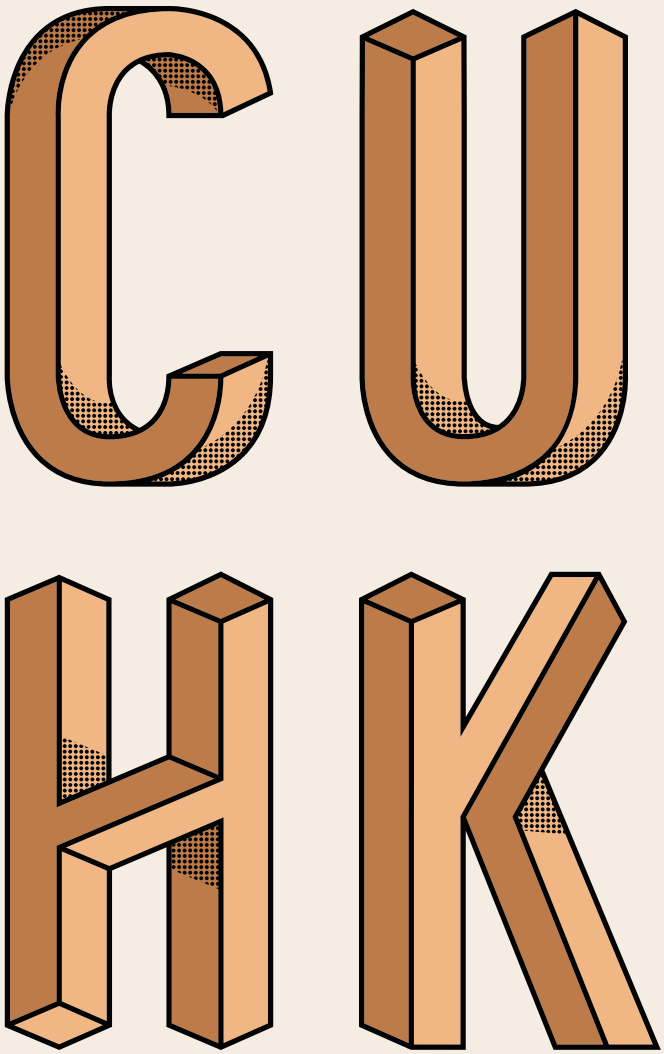
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DETAIL

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