Research Assessment Exercise 2020
Impact Case Study

University: City University of Hong Kong
Unit of Assessment (UoA): 15. chemical engineering, biomedical engineering, other technologies (incl. environmental engineering & nautical studies) and marine engineering
Title of case study: Invention of Electrophysiological and Inertial Motion Detection Systems

(1) Summary of the impact

Movements are reflections of the human status, from one's muscular actions to locomotion. The research team led by Dr. Raymond H. W. Lam and Dr. Chung Tin from City University of Hong Kong (CityU) has developed multiple advanced systems with real applications. These include ultrasound-based non-contact motion sensors, and biopotential sensing technology for electromyography, electrocardiography and electroencephalography for disease diagnosis, ambulatory monitoring and rehabilitation. The team developed motion sensing/positioning systems for applications such as surgery assistant and interactive modules applied in public/commercial exhibition platforms. This research has been supported by two Innovation and Technology Funds [1][2]. The work lead to publication of three international journal papers [3][4][5] and two patents [6][7] as well as contributing to various projects (with a grand total of over HKD30M) in collaborating companies [B]. It was presented in a number of exhibitions and reported widely in the TV news and the media [A][C].

(2) Underpinning research

This impact case involves multiple projects and activities by the research teams led by Dr. Raymond H. W. Lam and Dr. Chung Tin from CityU, which are listed as follows.

1. The team has developed patented technology of a micro-engineered conductive elastomeric electrode for measurements of human bio-potentials with the absence of conductive pastes/gels [5][7]. Mixing the biocompatible polydimethylsiloxane (PDMS) silicone with other biocompatible conductive nano-particles further provides the material with an electrical conductivity. These micro-structures can maintain the electrical impedance of materials and the bio-signal quality under the physical stretch by the movement of the human body. The team demonstrated the working performance of these micro-engineered electrodes throughout the development of product prototypes: 1) A biosensing vest for the acquisition of the 12-lead electrocardiographs (ECG) [1], and 2) a biosensing hat for electroencephalography (EEG) [2]. The gel-less micro-engineered electrodes can provide a more convenient and stable bio-potential measurement platform, making tele-medical care more achievable with reduced technical barriers for instrument installation performed by patients/users themselves.

2. The team has developed artificial intelligence strategy for improved biopotential sensing. Hand movement classification based on surface electromyography (sEMG) pattern recognition is a promising approach for upper limb neuroprosthetic control. However, maintaining day-to-day performance is challenged by the non-stationary nature of sEMG in real-life operation. The team invented a self-recalibrating classifier that can be automatically updated to maintain a stable performance over time without the need for user retraining. The classifier is based on convolutional neural network (CNN) using short latency dimension-reduced sEMG spectrograms as inputs [4]. The pretrained classifier is recalibrated routinely using a corrected version of the prediction results from recent testing

sessions. The system was evaluated with the NinaPro database comprising of hand movement data of 40 intact and 11 amputee subjects. The system was able to achieve ~10.18% (intact, 50 movement types) and ~2.99% (amputee, 10 movement types) increase in classification accuracy averaged over five testing sessions with respect to the unrecalibrated classifier. When compared with a support vector machine (SVM) classifier, our CNN-based system consistently showed higher absolute performance and larger improvement as well as more efficient training. These results suggest that the proposed system can be a useful tool to facilitate long-term adoption of prosthetics for amputees in real-life applications.

3. Damage to the brain, as a result of various medical conditions, impacts the everyday life of patients and there is still no complete cure to neurological disorders. Neuroprostheses that can functionally replace the damaged neural circuit have recently emerged as a possible solution to these problems. The team developed a real-time cerebellar neuroprosthetic system to substitute neural function in cerebellar circuitry for learning delay eyeblink conditioning (DEC) [3].

4. The team also invented a patented technology for non-contact motion sensing [6]. Users are only required to hold an object identification module. While multiple sensing spots in an indoor venue emit and detect ultrasounds, the user's location and his/her posture can then be measured. This technology offers real-time motion sensing and therefore it is particularly applicable in user-machine interactions, such as the interactive exhibition products.

(3) References to the research

Funded Projects

[1] "Flexible Intelligent Electrocardiography Jacket Based on Polymer Microengineering", Innovation and Technology Fund (ITF), ITS/084/12, ~HKD 1M, Nov 2012 – Apr 2014.

[2] "An Ambulatory Electroencephalographic System for Long-term and Portable Monitoring of Epilepsy Patients", Innovation and Technology Fund (ITF), ITS/263/14, ~HKD1.4M, May 2015 – Jun 2017.

Publications

[3] T. Xu, N. Xiao, X. L. Zhai, P. K. Chan, C. Tin, "Real-time Cerebellar Neuroprosthetic System based on a Spiking Neural Network Model of Motor Learning", Journal of Neural Engineering, 15(1):016021, 2018.

[4] X. L. Zhai, B. Jelfs, R. H. M. Chan, C. Tin, "Self-Recalibrating Surface EMG Pattern Recognition for Neuroprosthesis Control based on Convolutional Neural Network", Frontiers in Neuroscience, 11:379, 2017.

[5] Dinglong Hu, Tin Kei Cheng, Kai Xie, and Raymond H. W. Lam, "Microengineered Conductive Elastomeric Electrodes for Long-Term Electrophysiological Measurements with Consistent Impedance under Stretch", Sensors, 15(10):26906, 2015.

Patents

[6] Alan H. F. Lam and Raymond H. W. Lam, "An Ultrasound-based Positioning System and Strategy", China Patent: ZL201410013314.5, Jun 2016.

[7] Raymond H. W. Lam, Tinkei Cheng and Dinglong Hu, "Apparatus for Detection of Electrical Signal of a Biological Subject and Electrode Thereof, and Method of Manufacture Thereof", US Patent, 10039466, Aug 2018.

(4) Details of the impact

The research team led by Dr Raymond H W Lam and Dr Chung Tin from CityU is active in the research and development of multiple advanced systems with real applications. To date, the team has developed two patented technologies on non-contact motion sensing. The involved research and development works were initially supported by CityU via the University internal grants. For one of the technologies on ultrasound-based motion sensing, the team further collaborated with Sengital Limited and applied for a China patent. The technology has been further developed by Sengital Limited and the motion-sensing technologies have been presented in more than 50 government-funded exhibitions, e.g. 2013 科學館的恐龍展「巨龍傳奇」, 2014 文化博物館的「宮崎駿特展」and 2015 「敦煌石窟」展覽, etc., in Hong Kong. The total attendants of these exhibitions are at over 10 million person-times, with a grand total of over HKD30M [B]. The list of events can be found in the letter dated 17 October 2019 from Dr. Alan Lam, CEO and Founder of Sengital Limited. [B]

On the other hand, the technology on the micro-structured gel-less stretchable bio-potential electrodes was first supported by CityU internal grants for the proof of concept results. With these results, this research was recognized and successfully granted with two Innovation and Technology Funds (ITFs). The technology on the electrode design and fabrication has obtained a US patent; and the further developed ECG vest technologies and the ECG analysis algorithm have been reported widely in the TV news and the media [A][C].

In addition, the team has been joining events to promote their research projects. Often, CityU coordinate with the exhibition organizers for providing us exhibition opportunities. Taking one recent activity as an example, two groups of students supervised by the team shared the innovative projects during a university event at the Hong Kong Convention and Exhibition Centre on 9 April 2019. This exhibition attracted more than 350 invited visitors from more than 200 companies from various industries.

On the other hand, these research ideas and prototypes are introduced to students of the department's undergraduate programme (B.Eng. in Biomedical Engineering) in the courses (BME2103 Medical Biotechnology, and BME4101 Biomedical Instrumentation) every year. There are already >300 students taken both these two courses; and some of them are already working as part of the biomedical industry in Hong Kong. These ideas have inspired some of the department's students to develop their own original prototypes. Notably, some students have won the Silver Award at HKEIA Innovation & Technology Project Competition 2016 [D].

(5) Sources to corroborate the impact

[A] Ambulatory Portable Electrocardiographic Jacket: Media coverage listed below are provided.
TV News: TVB news (2 April 2014, 7:32 pm, 1 min 58 s), ATV news (2 April 2014), On TV / 東網電視 (2 April 2014, 38 s)

Newspapers: "城大研智能緊身衣遙距監察心跳", Ming Po / 明報; "城大研智能緊身衣 遙距監測異常心跳", Headline Daily / 頭條日報; "城大研發智能心電緊身衣可遙距監測心臟病人狀況", Tai Kung Pao / 大公報; "城大學者研緊身衣測心電圖 全球首創 心跳異常提示醫院", Sing Tao Daily / 星島日報; "城大研發 適合罹疾獨居長者 心電緊身衣遙距測病況", Hong Kong Daily News / 新報; "城大智能心電衣 遙距觀察獨居", Wen Wei Pao / 文滙報; "城大研發智能緊身衣測心臟", Macau Daily / 澳門日報; "首創智能緊身衣 助長者監測心跳情況", AM730; "醫知健：心電緊身衣全天候監察", The Sun, 太陽報; "智能衣救心病",

Metropolis Daily / 都市日報; "City University researchers develop life-saving 'smart' shirt that can detect heart problems", South China Morning Post / 南華早報; "New `shirt' gets to heart of problem", The Standard / 英文虎報; "智能緊身衣 遙距追蹤心臟病者", Hong Kong Economic Times / 經濟日報; "智能衣監測心臟 遙距知異常", Sky Post / 晴報; "發警報心電緊身衣智能保護你", Oriental Daily News / 東方日報; "智能緊身衣遙距監察心臟病", Hong Kong Commercial Daily / 香港商報; "城大學者研發智能緊身衣監測病人心肌活動", CityU News Centre / 城大新聞網; "城大學者研緊身衣測心電圖", Sina Hong Kong / 香港新浪網; "城大學者研緊身衣測心電圖", Yahoo Hong Kong / 香港雅虎網

[B] **Applied Applications:** The support letter from Sengital and related media coverage listed below are provided.
The total revenue of this technology transfer project has been HKD ~30M since 2013. (Ref: Alan Lam, CEO of Sengital*), related to the technologies applied in multiple exhibitions, e.g. 2013 科學館的恐龍展「巨龍傳奇」、2014 文化博物館的「宮崎駿特展」and 2015 「敦煌石窟」展覽, etc.

[C] **Drunk-Driving Prevention Based on Electrocardiographic Monitoring:** Media coverage listed below are provided.
(8 Mar 2017) 城大展師生發明 產品助弱勢 [Wen Wei Po], (22 Jun 2017) 城大創新展 析心電圖偵醉駕 [Wen Wei Po], (22 Jun 2017) 學生研發：電子科技探測防醉駕 導航系統化身手術助手 [am730], (22 Jun 2017) 城大防醉駕系統 測心電圖防意外 [Sing Pao Daily News]

[D] **EMG-driven Rehabilitation Orthotic Hand:** Media coverage for below is provided.
Silver Award at HKEIA Innovation & Technology Project Competition 2016 by BIE students: Yu-Hsuan Huang, Kwan Yi Mak, Ka Ying O, Hau Ching Wong and Hoi Yi Stephanie Yau on their project "EMG-driven Rehabilitation Orthotic Hand" under the supervision of Dr. Chung Tin.