Shun Hing Institute of Advanced Engineering

信興高等工程研究所

Research Highlights
2008–2012

SHIAE

香港中文大學
The Chinese University of Hong Kong

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For further information, please visit our website: http://www.shiae.cuhk.edu.hk

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Message from the Vice-Chancellor

It is my great pleasure to write at the head of the second quinquennial report on the work of the Shun Hing Institute of Advanced Engineering. My warm congratulations go to Professor P. C. Ching, the Director, and his colleagues for another five years of outstanding and rewarding research, and I would also like to extend my heartfelt gratitude to members of its International Advisory Board, for their sage advice and wise counsels. The Institute owed its establishment to the generosity of the Shun Hing Group and its founder, the late Dr William Mong, to whom we are eternally grateful for their time-honoured interest in the development of this University. The Institute is now one of the centres of excellence that have brought prestige and just pride to The Chinese University of Hong Kong.

The Institute is entering its tenth year, at a time when the University celebrates its fiftieth anniversary and the Shun Hing Group its diamond jubilee. It is most regrettable that Dr Mong is no longer with us for the events and activities commemorating the foundation of our respective institutions, but we are much encouraged by the fact that the enthusiasm of the Mong family in the education of young people, and the advancement of higher learning, has gained renewed momentum with Mr David Mong as head of the Shun Hing enterprise, and look forward to many future occasions of working together with him and his associates.

Let us dedicate this volume to the memory of the late Dr William Mong, whom we will always cherish in our hearts. ***Si monumentum requiris, circumspice*** (If you seek monuments in his honour, just look around)* would certainly be an apt expression of our thoughts and respect.

Joseph J. Y. Sung
Vice-Chancellor and President

*Epitaph on the tomb of Sir Christopher Wren in St Paul's Cathedral, London, who rebuilt the metropolis after the Great Fire of 1666.

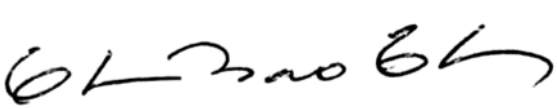
Foreword

Since its inception in 2004, the Shun Hing Institute of Advanced Engineering (SHIAE) has enjoyed the support and generosity of the late Dr. William Mong and the continued support of his son, Mr. David Mong. The progress and innovation we have made in leaps and bounds would not have been possible without the unwavering support of the Shun Hing Group and their dedication to improving society and the living standards of citizens through technological advancement. The success of the Institute is largely due to our shared goals and commitment to the betterment of society.

During the eight years that SHIAE has been in operation, we have maintained our prestigious position as pioneers in our fields of research. We have undertaken 41 research projects, both basic and applied, of high academic merit in the three major areas of biomedical engineering, multimedia technologies and renewable energy. We have produced many world-class scientific and technical results, leading to new knowledge and technological deployment. A total of 250 articles have been published in top-tier international journals and/or presented at flagship conferences. This would not be possible without the tireless dedication of everyone involved, from our research teams and other staff to visiting scholars and fellows. Together, we can continue our growth and development and remain at the forefront of advanced research and strengthen our links to industry and other engineering institutions to facilitate the sharing of knowledge and innovation.

It is my extreme fortune, honour and privilege to continue working with Shun Hing in this special year of their 60th anniversary. The 60th anniversary (or Diamond Jubilee) is an auspicious event; although in Chinese culture it signifies the end of a cycle, it brings with it a new beginning and ushers in a new era. Change is inevitable for progress and improvement; by embracing it, Shun Hing has been able to prosper and thrive for the past sixty years. It is commendable that throughout the changes over the years they have stayed equally committed and dedicated to giving back to the community and their mission in using technology to improve quality of life. For every success that came their way in the past sixty years, they have shared it generously with the community – by supporting students and schools, they have been investing in the future.

The graceful philanthropic act of Shun Hing has shone forth its diamond rays on the academia. We are immensely appreciative that Mr. David Mong is continuing his father's legacy – their generous support has not only benefited us at SHIAE, but also others including many tertiary education institutions. Regretfully, Dr. William Mong is no longer with us to celebrate another anniversary of Shun Hing and SHIAE, but his spirit lives on through his son, his work, and his contributions which have had a lasting impact not only on SHIAE but also on the entire engineering world. I sincerely wish Shun Hing continued success in all their endeavours, as we continue our journey of discovery and innovation hand in hand.



Pak-Chung Ching
Pro-Vice-Chancellor and Vice-President
Director, Shun Hing Institute of Advanced Engineering

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Introduction of SHIAE

Mission of SHIAE

The MISSION of the Institute is to spearhead, conduct, promote and co-ordinate research in advanced engineering. There is no end to the list of areas to be explored and the plan is to give priority to research topics that are both exciting and innovative. The Institute also aspires to transferring its research results to industry for practical application and to put across to the community at large the role of engineering as a driving force for human development through educational activities.

As a pioneering institute exploring the forefront of the engineering science, The Shun Hing Institute of Advanced Engineering will

» spearhead state-of-the-art advanced engineering research
» create and sustain synergy with world-class researchers
» develop with and transfer to industries cutting edge technologies
» promote appreciation of engineering in society through educational programmes

The Shun Hing Institute of Advanced Engineering is a strategic initiative of The Chinese University of Hong Kong dedicated to excellence and innovation in the research and development of advanced engineering relevant to Hong Kong and the region. It is established through the generous funding support of the Shun Hing Education and Charity Fund, a splendid example of crossover partnership between the private sector and a tertiary institution. It is the first and most excellent of its kind.

The Shun Hing Education and Charity Fund was founded by Dr. William Mong Man Wai with the aim of enhancing educational opportunities for the younger generations. The Fund has already sponsored numerous educational and research programmes in Hong Kong, the Mainland, and overseas educational institutions. Himself an engineer and a firm believer in advancing the quality of life through the development of science and technology, Dr. Mong had been there to support the establishment and growth of this Institute from the beginning.

Centre of Excellence at CUHK

The Chinese University of Hong Kong is an internationally renowned institution of higher learning devoted to quality teaching and both academic and applied research. The University has established 29 research institutes and a number of research centres with a view to pursuing up-front research endeavours with focused goals and objectives. The Shun Hing Institute of Advanced Engineering plays a crucial part in the research infrastructure of the Chinese University which is committed to exciting research programmes in advanced engineering areas.

As a strategic centre of excellence at The Chinese University of Hong Kong, the Institute supports greater regional and international research collaborations, and strives to attract talent from the world over to achieve greater internationalization, a vision strongly advocated by every member of the University.

Commitment of the Faculty of Engineering

The Faculty of Engineering was founded in 1991 and was built upon existing strengths with added talent from all over the world. The Faculty has been able to attract some of the best minds. Many received their training in leading universities in North America, Great Britain and Australia. Most of them have extensive experience in industry and many are leaders in their fields. This team of top-notch talent is gathered to nurture local talent through educational programmes, and break new frontiers in research through innovative and exciting research endeavours.

The positioning of The Shun Hing Institute of Advanced Engineering in the William M.W. Mong Engineering Building is deliberate as a key nucleating point to integrate research endeavours in the Engineering Faculty and its neighbours. Our members join hands with their counterparts from the Faculties of Science and Medicine in many interesting research collaborations. It is the ambitious goal of the Faculty of Engineering that the Institute should become a lighthouse for the local technology landscape to herald the migration towards high value-added technology and an information economy.

The mission of the Institute is to spearhead, conduct, promote and co-ordinate research in advanced engineering. There is no end to the list of areas to be explored and the plan is to give priority to research topics that are both exciting and innovative. The Institute also aspires to transferring its research results to industry for practical application and to put across to the community at large the role of engineering as a driving force for human development through educational activities.

Building on Strength and The Way Ahead

Many of the Institute's research projects are built upon areas in which the Faculty has already achieved outstanding performance. These are areas that have great potential for further technological advancement and in line with industrial development in Hong Kong. The Institute provides a vibrant R&D environment to spur new discoveries and speed up their translation into applications. Since 2012, we have expanded our scope to cover new frontiers in Renewable Energy striving to answer tomorrow's energy challenges.

Technology Transfer

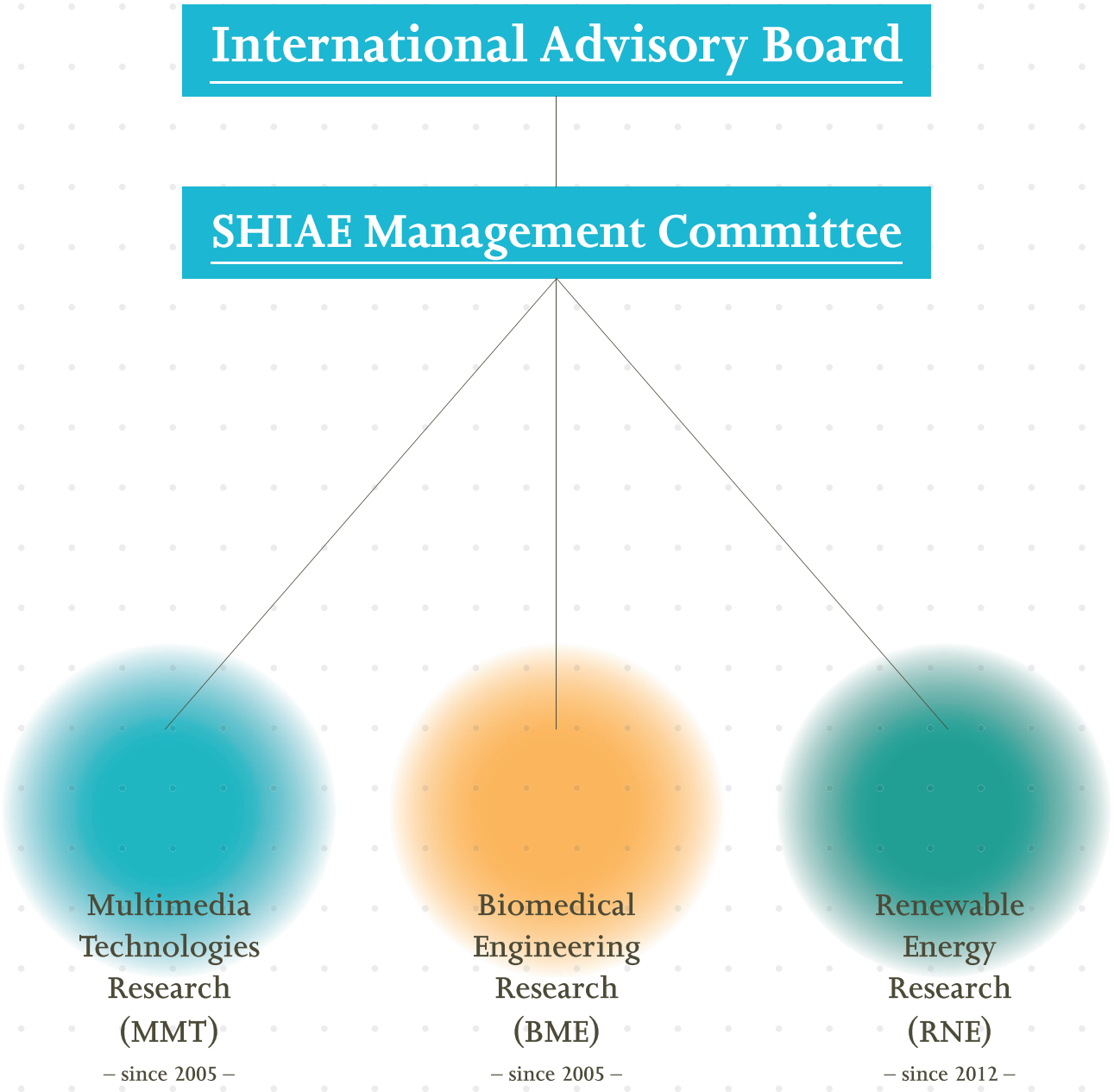
Synergy with industry is the ultimate goal of research and development in Hong Kong. External experts have been brought in to the Institute to lead research projects that could benefit the industrial sector.

The technology transfer arm of the Faculty of Engineering plays an important role in the traffic between the Institute and industry. The Institute houses an array of top-notch research and development activities encompassing contract research, spin-off companies, and consultancies.

Contribution to Society

The Institute has been making contributions to the progress of Hong Kong through a wide range of educational activities like training courses, seminars, symposiums which disseminate the latest technologies to promote appreciation of engineering in society and arouse interest of the younger generations in engineering.

Organization of SHIAE



We also provide support and sponsorship to the Faculty of Engineering in organizing prestigious academic conference in Hong Kong so as to raise our international profile.

Composition of International Advisory Board

(with effect from 1 August 2010)

Chairman:

Mr. David T.Y. MONG 蒙德揚先生

Managing Director
Shun Hing Electronic Trading Co., Ltd.,
Hong Kong

Members:

Professor Victor ZUE

Professor of Electrical Engineering and Computer Science
Massachusetts Institute of Technology,
U.S.A

Dr. Harry SHUM 沈向洋博士

Corporate Vice President
Microsoft Corporation,
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Professor Yongmin KIM

Hunter and Dorothy Simspon Endowed Chair in Bioengineering
Department of Bioengineering, University of Washington,
U.S.A.

Professor Chih-Ming HO 何志明教授

Ben Rich-Lockheed Martin Professor in School of Engineering
University of California, Los Angeles,
U.S.A.

Professor C.C. Jay KUO

Professor of Electrical Engineering and Computer Science
University of Southern California,
U.S.A.

Professor Jack C.Y. CHENG 鄭振耀教授

(until 31 December 2012)

Pro-Vice-Chancellor
The Chinese University of Hong Kong
Hong Kong

Professor Tai Fai FOK 霍泰輝教授

(with effect from 1 January 2013)

Pro-Vice-Chancellor
The Chinese University of Hong Kong
Hong Kong

Professor Wing-shing WONG 黃永成教授

Dean of the Graduate School
The Chinese University of Hong Kong
Hong Kong

Professor Ching Ping WONG 汪正平教授

Dean of Engineering
The Chinese University of Hong Kong
Hong Kong

Professor Pak Chung CHING 程伯中教授

Director of Shun Hing Institute of Advanced Engineering
Pro-Vice-Chancellor and Professor of Electronic Engineering
The Chinese University of Hong Kong
Hong Kong

Composition of Management Committee

(with effect from 1 August 2011)

Director:

Professor Pak Chung CHING
Pro-Vice-Chancellor
Professor of Electronic Engineering

Secretary:

Professor John C.S. LUI
Professor of Computer Science and Engineering

Members:

Professor Ching Ping WONG (ex-officio)
Dean of Faculty of Engineering

Mr. Terrence CHAN
Managing Director of Shun Hing Technology Co., Ltd
Hong Kong

Professor Dennis Y.M. LO
Associate Dean (Research) of Faculty of Medicine
Professor of Chemical Pathology

Professor Wing-shing WONG
Dean of Graduate School
Professor of Information Engineering

Professor Ronald C.K. CHUNG
Professor of Mechanical and Automation Engineering
(until 10 December 2012)

Professor Michael Yu WANG
Professor of Mechanical and Automation Engineering
(with effect from 10 December 2012)

Professor King-Lap WONG
Professor of Mechanical and Automation Engineering
(with effect from 1 June 2013)

Professor Max Qing Hu MENG
Professor of Electronic Engineering

Professor Helen M.L. MENG
Professor of Systems Engineering &
Engineering Management

Core Members of Research Teams

Biomedical Engineering Track:

Faculty of Engineering

Professor Lai-Wan CHAN
Professor Pheng-Ann HENG
Professor Aaron H.P. HO
Professor Philip H.W. LEONG
Professor Wei-Hsin LIAO
Professor Wen-Jung LI
Professor Emma MacPherson
Professor Max Q.-H. MENG
Professor William S.-Y. WANG
Professor Ke-Li WU
Professor Yuan-Ting ZHANG

Faculty of Medicine

Professor Jack C.Y. CHENG
Professor K.S. LEUNG
Professor Mary Miu Yee WAYE
Professor Daniel T.P. FONG

Multimedia Technologies Track:

Faculty of Engineering

Professor P.C. CHING
Professor Dah-Ming CHIU
Professor Ronald C.K. CHUNG
Professor Kin-Chuen HUI
Professor Leo Jiaya JIA
Professor Tan LEE
Professor Jack Y.B. LEE
Professor Wen-Jung LI
Professor John C.S. LUI
Professor Michael Rung-Tsong LYU
Professor Helen M.L. MENG
Professor King-Ngi NGAN
Professor Raymond YEUNG

Renewable Engineering Track:

Faculty of Engineering

Professor Shih-Chi CHEN
Professor Micheal Yu WANG
Professor Dongyan XU
Professor Ni ZHAO

Shun Hing Visiting Scholars / Fellows

The Institute has launched a Shun Hing Distinguished Scholar Program with an aim to attract distinguished scholars to pursue research collaboration with our faculty and to strengthen our research profile. The following scholars visited to work either on a short term or on a longer term engagement with the Institute between 2008 and 2012.

Shun Hing Visiting Scholars:
(in alphabetical order)

Professor Francois BACCELLI 2011
INRIA and Crole Normake Superieure, France

Dr. Tao GONG 2008
University of Rome-La Sapienza, Italy

Dr. Jun HE 2010
Nanjing University of Information Science and Technology, China

Professor Willem Bastiaan KLEIJN 2011
Victoria University of Wellington, New Zealand

Professor Ying-Yee KONG 2010
Northeastern University, USA

Dr. Chiaying LEE 2010
Institute of Linguistics, Academia Sinica, Taiwan

Professor Mark LIBERMAN 2010
The University of Pennsylvania, USA

Dr. Shengjun LIU 2009–2010
University of the Arts London, UK

Professor Armand M. MAKOWSKI 2012
University of Maryland, USA

Professor Sanjit K. MITRA 2010
University of Southern California, USA

Dr. Chuanlai SHEN 2009
Southeast University Medical School, China

Professor Lianfeng SHEN 2012
Southeast University, China

Dr. Sigfrid D. SOLI 2009, 2010, 2012
House Ear Institute, LA, USA

Professor Chiu-yu TSENG 2010
Institute of Linguistics, Academia Sinica, Taipei, Taiwan

Dr. Penelope Ann WATKINS 2008
University of the Arts London, UK

Dr. Meng YUAN 2010
Institute of Acoustics, Chinese Academy of Sciences, China

Professor Wei ZHANG 2012
The University of New South Wales, Australia

Shun Hing Fellows and Research Associate:
(in alphabetical order)

Dr. Kwong Wah CHAN 2008
The Chinese University of Hong Kong

Dr. Yang CHEN 2008–2010
Southern Medical University, Guangzhou, China

Dr. Hui CHENG 2011–2012
Thu Sun Yat-sen University, China

Dr. Jinzhou CHIEN 2009–2010
The Chinese University of Hong Kong

Dr. Jun HE 2010–2011
Nanjing University of Information Science and Technology, China

Dr. Jia LI 2008–2009
The Chinese University of Hong Kong

Dr. Peng LI 2010–2011
The Chinese University of Hong Kong

Dr. Lu LIU 2008–2009
The Chinese University of Hong Kong

Dr. Lu LU 2012–2013
The Chinese University of Hong Kong

Dr. Yangjun LUO 2012–2013
Northwestern Polytechnical University, China

Dr. James William MINETT 2008–2010
The Chinese University of Hong Kong

Dr. Wanli Ouyang 2011–2012
The Chinese University of Hong Kong

Dr. Edward Philip John PARROTT
University of Cambridge, 2010–2012
United Kingdom

Dr. Samar 2012
Indian Institute of Science, India

Dr. Wenyan TAO 2010–2012
The Chinese University of Hong Kong

Dr. Dai-Hua WANG 2008
Chongqing University, China

Dr. Feng WANG 2012–2013
The Chinese University of Hong Kong

Dr. Xiaoming WANG 2012–2013
Dalian University of Technology, China

Dr. Xiaona WANG 2008–2010
The Chinese University of Hong Kong

Dr. Zhehua WU 2008
The Chinese University of Hong Kong

Dr. Huihua XU 2012–2013
Chinese Academy of Science, China

Dr. Lisheng XU 2008–2009
Harbin Institute of Technology (HIT), China

Dr. Juekuan YANG 2012–2013
Southeast University, China

Dr. Shih-Mo YANG 2012–2013
National Chiao Tung University, Taiwan

Dr. Hong YAO 2012–2013
The Chinese University of Hong Kong

Dr. Lei ZHAO 2008–2009
The Chinese University of Hong Kong

Research Activities

- Technology Transfer
- Academic Publications
- Research Reports

Technology Transfer

To comply with the mission of the Institute, SHIAE is strived to transfer its research results to industry for practical application, some technology transfer planning are listed here.

"An inexpensive functional finger prosthesis with rebounded type progressive hinge lock"

(Project funded in Year 2009)

by Professor Daniel Tik Pui FONG

Department of Orthopaedics and Traumatology, CUHK
Division of Biomedical Engineering, CUHK

The device allows user to regain flexion and extension movement of finger. This project aims to design an inexpensive artificial finger which is affordable to most people, especially those factory workers losing their fingers due to occupational injuries.

The design (Figure 1) makes use of a rebounded type progressive hinge lock which is often used in chairs, seats and sofas for adjusting the back support angle. The "progressive hinge lock" allows the joint to be bent easily in one direction and locked against the opposite force. In this prosthesis, the joint starts working from zero flexion and then flexion is performed by assistance of another hand, with 15 degrees increment, until a 90-degree flexion is reached. At each of the interval, the joint is locked to prevent extension of finger. This makes possible the thumb opposition nature of human hand for amputee. When the flexion angle exceeds 90-degree, it rebounds and returns to starting position.

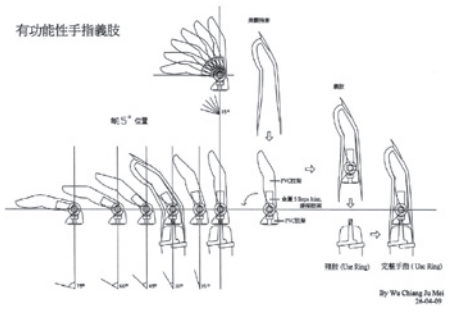

Figure 1. The design and the operation of the finger prosthesis

Figure 2. Several versions of prototype

The designs of joint, ring and tip structure were completed (Figure 2). Assembly method for different parts was also decided. Several versions of prototype were fabricated and tested. The joint thickness and weight was optimal. Also, the size and shape of ring was modified for better attachment to joint.

There were two attachment methods: (1) A non-invasive ring like structure was designed to attach the prosthesis to the stump of the metacarpal bone surrounding with muscles and soft tissue. The ring was made of sliver metal that allows easy and fine adjustment with manual strength. (Figure 3), (2) A silicon socket was designed for easy fitting for different patients. A serial of silicon sockets with different size was made. It is easy to mold to fit the patient's residue by heating. Moreover, it is much cheaper than sliver ring. (Figure 4). A traditional silicon prosthesis can be used to cover the prosthesis to improve the appearance.

Figure 3. A non-invasive ring like structure for attachment

Figure 4. A set of silicon socket with different size

Figure 5. Pick up a heavy object with the help of prosthesis

Efficacy of the finger prosthesis was evaluated by clinical biomechanics tests. The time required for picking up small objects was reduced by 21%. The prosthesis also allowed a patient to restore opposition function of the fingers, and to successfully pick up heavy object (Figure 5).

Commercialization plan

The feedback from the patients who have tried our invention was very good, and we believe that the invention would be a good device for us to prescribe to the patients through our Prosthetics and Orthotics services. We have applied US Provisional Patent for this invention, and are very interested to negotiate with industrial partners for successful commercialization. Currently we are in contact with one partner for a license, and we shall work towards a useful and inexpensive device to help the amputated patients.

"Development of an Efficient Locomotion Mechanism for Wireless Active Capsule Endoscope"

(Project funded in Year 2008)

by Professor Max Q.-H. MENG

Department of Electronic Engineering, CUHK

Wireless capsule endoscope, which is equipped with a micro-camera and wireless communication capability, has been proved to be an established device for examination of the gastrointestinal (GI) diseases. In clinical practices, capsule endoscopy can eliminate the patients' pain and examine the whole GI tract in a relatively effective way. However, the passive movement of the capsule without any control method often results in missing diagnosis, and makes the extended observation of interested spots impossible. To tackle the problem, we worked on the next generation wireless active capsule endoscope with actuation mechanism and localization system, with which a controlled interactive GI tract examination can be achieved.

We adopted a hybrid actuation mechanism which combined the internal actuator and the external magnetic guidance. This strategy can achieve adequate actuation force for the capsule to move inside the gastrointestinal tract while reduce the complexity of the external magnetic field at the same time. For the localization, which aims to find the exact position of the capsule, we took advantage of the magnetic field as well. A sensor array consisting of 3-axis magnetoresistive sensors was implemented to track the small magnet enclosed inside the capsule in real-time. The accuracy can reach 1mm, much more accurate than the current available tracking system (37.5mm). The developed device can be controlled to examine and stop at any interested spots of the GI tract and can be guided to move through unimportant areas of the GI tract in a much faster pace than the passive natural human peristaltic GI movement so that it has the advantages of both the wired endoscopes and the wireless passive ones.

We also developed an Intestinal Polyp Detection System to shorten the time for reading over 50,000 images per check, and provide comprehensive assistance to physicians in intestinal diagnosis. The system developed analyses the hue, saturation and intensity of each image to sort out images showing polyps according to their colors and shape features. We have tested the system with intestinal photos of local patients and found that its accuracy reaches 94.2%, far better than the 50% achieved by similar systems developed in other countries.

In 2010, the related research work has been publicized by 12 local newspapers after we held a press conference about the project and innovative results achieved. In later this year, the research project was featured at the Inno Carnival in HKSTP as a highlight project. Many visitors at Inno Carnival participated in the interactive demonstration we prepared, to experience the research achievements of our project. After the event, a NASDAQ listed HK company expressed their interest to our project and initiated collaboration on the potential commercialization of the products from our project. In 2011, our project was featured as part of the CUHK delegation at the ICT Expo. The new technology was also promoted among the public on Faculty of Engineering 20th Anniversary Innovation and Technology Fair, CUHK.

Given Imaging, the leading company in wireless capsule endoscope, shows great interest in our work. In 2012 they initiated a web meeting on the potential technology transfer, in which we reached an agreement on the participation of solving a challenging problem in active wireless capsule endoscopy. In 2013, they contacted us again and talked about possible collaborations with our research group. The Chairman of Chongqing Jinshan Science and Technology Co., the 2nd marketing company of WCE in the World and the only manufacturer of WCE in China, contacted us several times, initiating collaboration intension. We are following up with them for substantial collaboration opportunities.

新法照腸瘜肉 1小時完成

【本報訊】是否患上腸癌或腸道出現腫瘤，往往都需內窺鏡檢查，中文大學研發出新腸道檢查技術，可於1小時內完成膠囊內窺鏡檢查，更可自動找出瘜肉及腫瘤位置，準確率逾9成，成本比現時低一半，整套系統最快可於2至3年推出。

中大研發 可操控膠囊

新研發的「無線驅動膠囊內視鏡系統」由中大電子工程學系教授孟慧虎及其團隊研發，研究人員於膠囊內加入定位系統，病人吞入膠囊後，膠囊可由人手操控，作出更詳細的檢查。

孟解釋，「現有系統跟隨腸的蠕動而自然移動，約8小時後才自然排出，但新系統可令膠囊做到想動就動，想停就停，能更準確鄭症。」系統定位的準確度亦提高，偏差由37.5毫米減至3毫米，最快一小時便能完成檢查。

準確率逾9成 成本減半

以現行做法而言，即使完成檢查，醫生往往要用兩小時檢閱複雜的數據，研究團隊的就同時研發「腸道瘜肉影像識別系統」，利用新研發的軟件分析數據，跟據色彩、飽和度及光度，自動找出有否瘜肉及流血等異常情況，醫生檢查數據時間可縮減至半小時，分析系統的準確率高達94%，比現時的5成準確率更高。

孟指，最快明年可推出「腸道瘜肉影像識別系統」，而「無線驅動膠囊內視鏡系統」則有待臨床實驗，最快要2至3年後推出。系統將於11月的創新科技嘉年華展出。

〔經濟日報〕 2010-10-28

"Hybrid Assistive Knee Braces with Smart Actuators"

(Project funded in Year 2007)

by Professor Wei Hsin LIAO

Department of Mechanical & Automation Engineering, CUHK

Exoskeleton systems that can assist disabled people have been investigated in recent years. However, most exoskeletons use DC motors as actuators and batteries as power sources. A DC motor consumes a lot of power

and limits the working time of the exoskeleton. Magnetorheological (MR) fluid is a smart fluid that can change its rheological behavior under applied magnetic field. In this project, we developed a new MR actuator for an assistive knee brace to provide assistance to the elderly or disabled. It is the first in the world for a single device to have three functions (motor, clutch, and brake). When active torque is desired, the motor and clutch functions work to transfer the torque generated by the motor to the leg; when passive torque is desired, the motor function is off and the MR actuator functions as a brake to provide controllable torque. The prototype of this MR actuator was fabricated and experiments were carried out to investigate the characteristics of the MR actuator. A testing structure was developed for testing the knee brace with the novel MR actuator.

Under the support of Shun Hing Institute of Advanced Engineering, this project started in 2007 and significant results have been obtained since then. Besides several conference and journal papers and book chapter, one technology disclosure (CUHK 09/ERG/318) was submitted to Technology Licensing Office (now Knowledge Transfer Office), The Chinese University of Hong Kong (CUHK). A US patent entitled 'Magnetorheological Actuators' was awarded on June 5, 2012 (U. S. Patent 8,193,670). A China patent application entitled 'Magnetorheological Device for Delivery and Control of Motive Force' was also filed on September 13, 2011 (China Patent Application, No. 10H80828CN).

Towards the studies on hybrid assistive knee braces with smart actuators, two students received their PhD degrees. Through participating in this project, a final year project report and MPhil thesis were also completed. One journal paper published in Smart Materials and Structures was one of the top 10 most cited articles published in 2010, from Scopus in September 2012. The PI of the project, Prof. Liao, was invited to give talks about assistive knee braces with smart actuators at Shanghai Jiao Tong University, Nankai University, CIMTEC 2012 in Italy, and three keynote lectures were given at international conferences in USA, Singapore, and Hong Kong in 2010, 2011, 2012, respectively. This project has also been showcased at China Hi-Tech Fair 2010, and InnoCarnival, Hong Kong Science Park, in November 2010.

A 'Press Conference' was arranged on 5 January 2010 by Centre for Innovation and Technology as well as the Communications and Public Relations Office, CUHK. This project was reported in the TV news (TVB-Jade, TVB-Pearl, ATV, and HKBN) on 5 January 2010, and reported by 14 local newspapers the next day (6 January 2010) – Ming Pao, Singtao Daily, Hong Kong Economic Times, Apple Daily, Oriental Daily, Wen Wei Po, Ta Kung Pao, South China Morning Post, AM 730, Metro, Headline Daily, Sing Pao, Hong Kong Commercial Newspapers, Hong Kong Daily News. A couple of news clippings are provided. Moreover, additional HK$994,554 from Hong Kong Innovation and Technology Commission was awarded to support the further development on 'Smart Assistive Knee Braces Utilizing MR Fluids' (ITS/308/09, Tier 3). Another grant entitled 'Magnetorheological Actuator with Multiple Functions' was also awarded (HK$662,400) by Research Grants Council. Human trials with more testing and refinement have been carried out. The developed assistive knee brace with MR actuator have the following advantages: compact in size, low power consumption, safe, and adaptive. Discussing with several companies is on-going regarding technology transfer or possible partnership for the developed technologies.

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醫坊

智能膝架助關節炎患者

「磁流變液」傳力支撐膝蓋

患上嚴重關節炎的患者，上落樓梯會出現困難。中大機械與自動化工程學系研發「智能混合助力膝架」，用上智能液體，能在不同的情況，如上落樓梯，改變硬度協助患者伸直或彎曲膝蓋，而且新膝架用電量較目前坊間的支撐架長一倍以上，預計兩年後可以推出市場。

本報記者

目前大多的膝部活動輔助儀器，均靠馬達驅動，但耗電量高，充電後只能使用一至兩個小時，而且患者使用時，欠缺柔韌度，令用者容易感到不適，甚至手受傷。

改變硬度助上落樓梯

中大機械與自動化工程學系教授廖維新，近年利用一種名爲「磁流變液」的智能液體，成功開發「智能混合助力膝架」，新膝架可支撐大腿至小腿，每當患者需要主動助力時，例如上樓梯時須伸直膝蓋，膝蓋位置磁流驅動器可將馬達產生的力量傳送到膝架上，給予使用者足夠的力量上落樓梯。

廖維新解釋，磁流變液是一種經控的智能液體，在不同強度的磁場下會變成不同硬度的半固體或變會液體，可發揮如軟墊般的緩衝功能，令膝架有足夠的柔韌度，用者一般不會感到不適。

教授獲選工程學會院士

同時，廖維新指出，磁流變液反應速度很快，只需要約十至二十毫秒（一秒有一千毫秒）就能夠轉換其狀態，可以快速產生人體活動時所需的助力。

廖維新稱，未來將爲新膝架進行人體測試，預計可在兩年後推出市場。

早前全過有三人獲選爲美國機械工程師學會選爲二〇〇九年院士，廖維新與該系另一名教授杜如虎爲其中兩人。

廖維新教授成功開發「智能混合助力膝架」。

Radical knee brace on sale by 2012

Maggie Ng

A Chinese professor has developed an innovative electric brace for people with weak or injured knees that will go on sale by 2012.

Professor Liao Weihsin's Hybrid Assistive Knee Brace uses a combination of electric motors and magnetic-rheological (MR) fluid, and will soon be tested by people.

The brace is designed to be worn by those with injuries, osteoporosis, weak knees and the elderly to give more support and comfort when walking.

Liao, from the department of mechanical and automation engineering at Chinese University, is the first person in the world to use the MR fluid in a multi-functional knee brace. This system improves on existing models that offer limited movement.

"It is unique as it combines a motor, clutch and brake. It will be lighter and smaller than existing knee braces," said Liao.

He says once his device has undergone human trials, it should be on sale in Hong Kong by 2012 and will cost about HK$15,000.

SCMP City2 (6/1/2010)

The Hybrid Assistive Knee Brace will make it easier for people who need it to walk freely. Photo: Sam Tsang

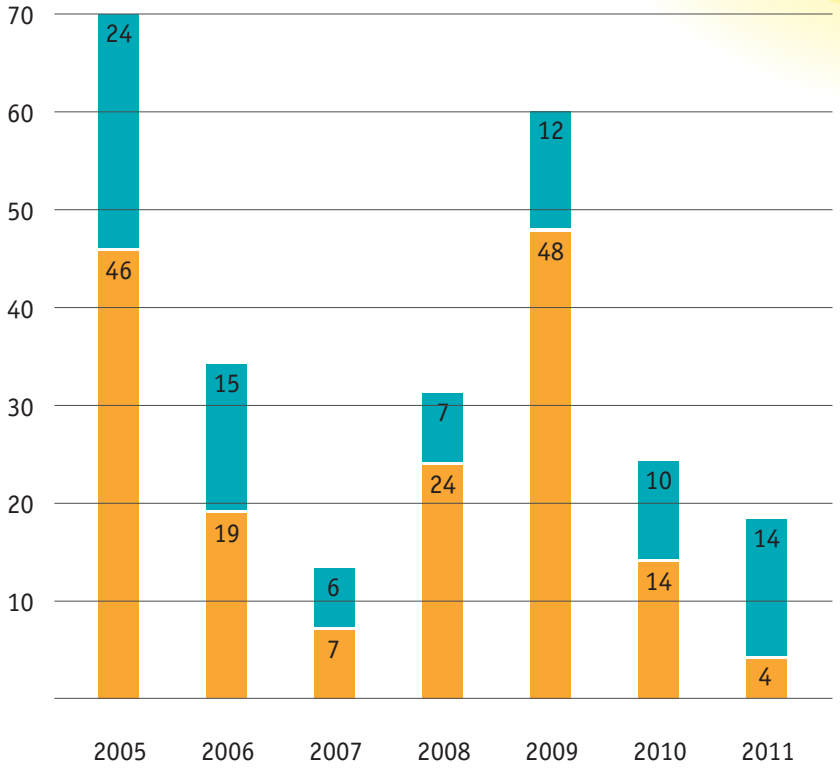
Academic Publications

So far 32 projects have been successfully completed and 250 articles arising from the results of these research projects have been published in international conference proceedings and journals. The other 9 on-going projects are also progressing well with encouraging results produced. The chart below shows the number of academic publications produced each year.

32
Completed projects

250
Academic Publications

Publications arising from SHIAE supported projects



The list of publications can also be downloaded from the webpage of SHIAE at www.shiae.cuhk.edu.hk/research.htm

Renewable Energy Track

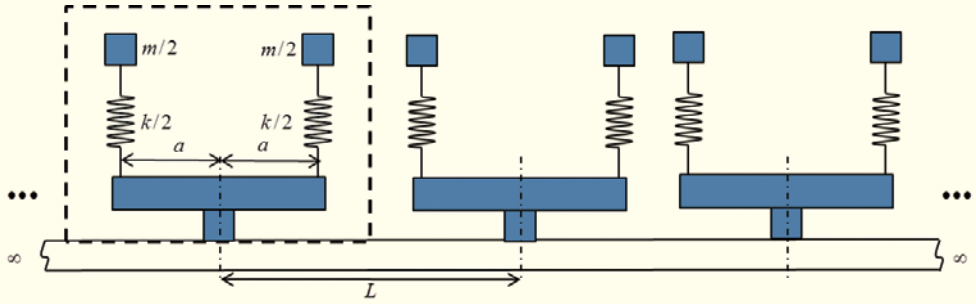
Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, and are derived from natural processes that are replenished constantly. In its various forms, it includes electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources. Renewable energy deployment and technological diversification of energy sources have significant benefits in energy security and economic development.

At the Faculty of Engineering, we have made substantial progress in our research mission of identifying, launching, and advancing innovative research directions in renewable energy technology, in addition to educating the next generation of renewable energy professionals and promoting diversity among faculty, research associates, staff, students, and future students.

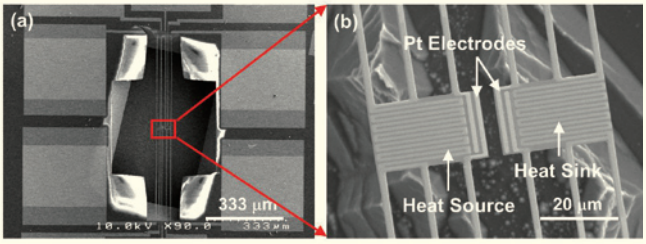
We harness the vibrant sustainable energy vision of the University, the extensive research resources of the Faculty and the University, and the growing regional and national interest to advance the solar, fuel cell and renewable energy technologies and research. We integrate cutting edge basic research in various disciplines into a powerful interdisciplinary mix to drive new research frontiers. We have identified three promising research directions—nanomaterials and nanostructures for future generation solar cell applications, transport property relation of boron carbide nanowires for battery, and vibration energy harvesting technologies. Our own seed program has been especially successful in exploring high-risk, high-payoff innovative research that can be integrated within the current research initiatives or translated to independent funding.

Specific projects to be pursued include:

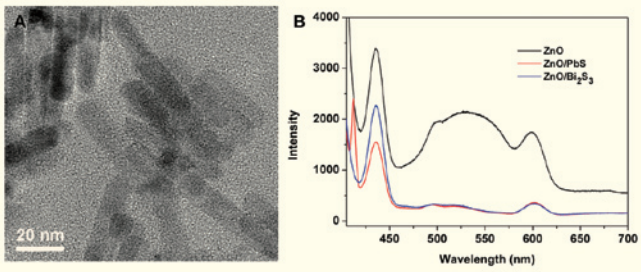
1 Vibration Energy Harvesting Utilizing Multifunctional Phononic Meta-Materials and Structures: We focus on a class of multifunctional, microstructured materials (meta-materials) and structures for vibration energy harvesting. By utilizing the multi-functional meta-materials and structures, vibration energy can be localized (or trapped); the vibration wave can be guided (or channeled) to a specific location; and multi-frequency waves can be separated (or filtered) into single-frequency parts. Consequently, the vibration energy can be collected, filtered, and finally channeled to and accumulated at converting locations, where it is converted into electrical power by piezoelectric harvesters with tuned resonances.



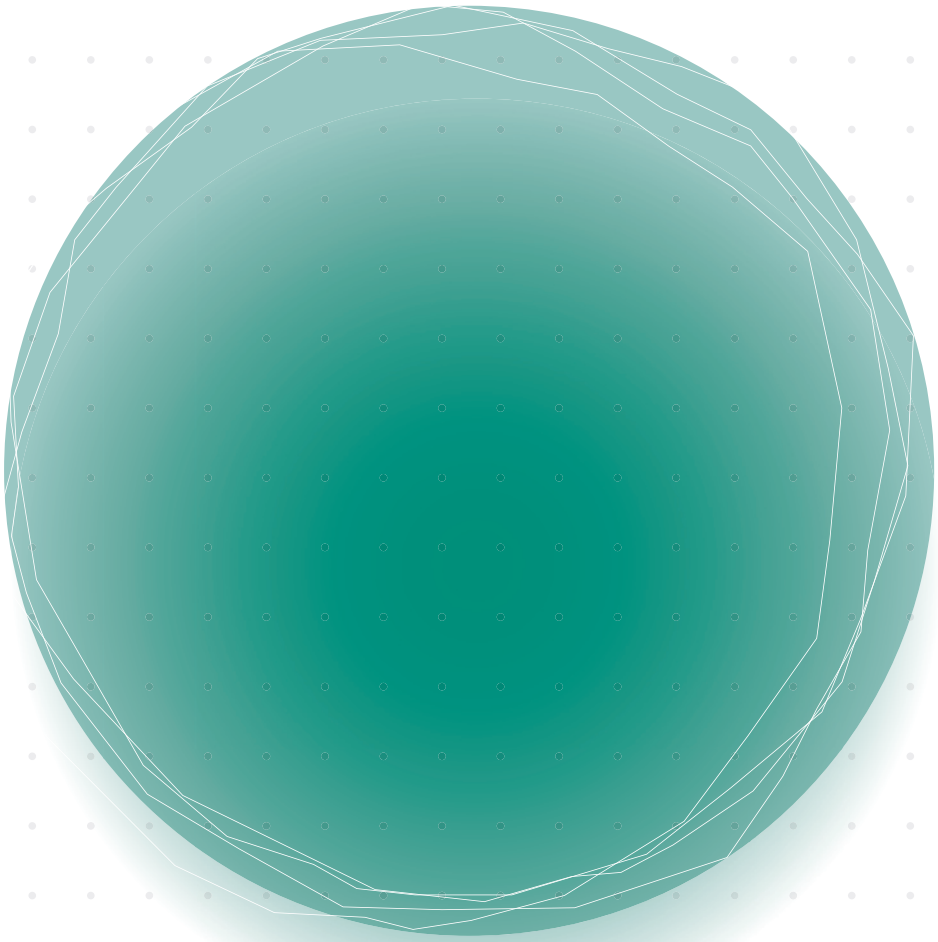
2 Understanding Electron and Phonon Transport in Boron Carbide Nanowires for Thermoelectric Energy Conversion: We study the structure and transport property relation of boron carbide nanowires for thermoelectric energy conversion applications. The approach is to integrate systematic transport property measurement on individual boron carbide nanowires and detailed structure and composition characterization for each measured wire. The ultimate goal is to develop the structure-transport property relations for boron carbide nanowires.



3 Ternary Hybrid Polymer/Nanocrystal Bulk Heterojunction Solar Cells with Cascade Energy-Level Alignmen: We create a cascade of energy levels in the photoactive layer of hybrid solar cells by utilizing a ternary BHJ structure. We will develop solution-based methods to fabricate two ternary BHJ structures, polymer/quantum dot/nanorod and polymer/nanoshell/nanorod. The fundamental understanding gained from this project will greatly benefit efforts to realize the next generation of solar cell technology.



Faculty members active in the research area of Renewable Energy Engineering are: Prof. Pheng Ann Heng of Computer Science & Engineering Department; Prof. Ni Zhao of Electronic Engineering Department; Prof. Michael Wang and Prof. Dongyan Xu of Mechanical and Automatio Engineering Department.



Research Reports

« Renewable Energy »

Continuing Projects (2012)

- Vibration Energy Harvesting Utilizing Multifunctional Phononic Meta-Materials and Structures
- Understanding Electron and Phonon Transport in Boron Carbide Nanowires for Thermoelectric Energy Conversion
- Ternary Hybrid Polymer/Nanocrystal Bulk Heterojunction Solar Cells with Cascade Energy-Level Alignmen

Vibration Energy Harvesting Utilizing Multifunctional Phononic Meta-Materials and Structures

Principal Investigator

Professor Michael, Yu WANG

Department of Mechanical & Automation Engineering, CUHK

Research Team Members

Xiaoming WANG, Shun Hing Research Fellow[1]

[1] Dept. of Mechanical and Automation Engineering, CUHK

| Reporting Period: 1 July 2012 – 30 December 2012 |

Abstract

Our project focuses on a class of multifunctional, microstructured materials (meta-materials) and structures for vibration energy harvesting. The meta-materials have superior mechanical wave handling properties and energy conversion capabilities. These abilities of meta-materials can inhibit elastic waves from propagating within specific frequency ranges known as phononic bandgaps. By utilizing the multi-functional meta-materials and structures, vibration energy can be localized (or trapped); the vibration wave can be guided (or channeled) to a specific location; and multi-frequency waves can be separated (or filtered) into single-frequency parts. Consequently, the vibration energy can be collected, filtered, and finally channeled to and accumulated at converting locations, where it is converted into electrical power by piezoelectric harvesters with tuned resonances.

1. Objectives and significance

Energy harvesting has become the talk of the engineering world. Generating electrical energy from natural or environmental sources, such as ambient vibrations and heat, would give self-powered capability to a sea of portable electronic devices, wireless sensors and MEMS systems. Vibration energy harvesting holds a great potential, as vibrations are omnipresent in machines and structures, scattering energy over wide space and in a wide frequency range. The challenge is to collect vibrations effectively and convert them efficiently into electricity, allowing energy harvesting on a continuous basis and employed in hostile and inaccessible environment.

The aim of this research project is to develop the multifunctional structures whereby meta-materials with desired bandgap functions are integrated as building blocks to form the structures for efficient energy harvesting. The proposed approach is hierarchical and is physically driven. The overall goal of the project is to develop the hierarchical design method and to demonstrate the applicability of the proposed vibration energy harvesting system. The proposed system is also scalable for microscale applications. It is expected that this investigation would yield a novel vibration energy harvesting technique that would significant advance the state-of-the-art.

The objectives of the project include:

1. Development of an optimization-based approach that employs level set methods to provide complex designs of bandgap meta-materials of multiple frequency-dependent dispersive dynamic characteristics;

2. Systematic explorations of unit cell optimization of meta-materials to optimize the three desired functional materials crucial to the proposed vibration energy harvesting structure: (1) trapping, to localize elastic waves of a specified frequency range, (2) channeling, to guide vibration waves to a specific location, and (3) filtering, to separate or select multi-frequency waves into single-frequency parts;

3. Hierarchical design for energy harvesting structures: (1) synthesizing the topology of bandgap structure with a layout of regions of the required multifunction meta-materials, and (2) employing the designed materials to form a bounded structure with bandgap functions that correlate with those of the materials in the structure;

4. Demonstration of the proposed approach with design cases where ambient vibration energy of a structure is filtered, accumulated and channeled for harvesting, showing the feasibility of the concept and the efficiency of the proposed phononic structure.

2. Research methodology

A key contribution of our approach stems from a complete understanding of the dynamics of periodic bandgap materials and structures. We embark upon the difficulties of ambient vibration sources characterized by their spatial distribution (location) and time distribution (frequency), as they are often generated from multiple sources, propagated throughout the structure and distributed over a large surface area. Their energy might be scattered over a range of frequency spectrum. Fortunately, phononic bandgaps can have multiple functions. A phononic material can disperse different wavelengths, stopping or letting pass a selected frequency and, thus, acting as a wave trap. We intend to utilize these fundamental dynamical properties and to construct bounded structures from bandgap materials such that they are to be used as basic functional building blocks for our novel multiscale multifunctional system for vibration energy harvesting.

3. Results achieved so far

During this period of the project, we focus on vibration energy harvesting with phononic bandgap structures. First, we study benchmark problems of bandgap materials and optimization. The problems include bandgap mechanisms for broadband frequency wave attenuation in low frequency range. We studied flexural beams with multi-DOF resonators attached, which generate locally resonant wave trapping. With the innovative use of different configurations of 2-DOF resonators, we have found very interesting properties of wave dispersion. Particularly, our preliminary results indicate that we can achieve super-wide frequency bandgaps at low frequency range. This is a scenario suited for harvesting the energy of the vibration wave with two piezoelectric harvesters with tuned resonance frequency. We will continue to investigate the properties to the full extend.

4. Publication and awards

Our research findings arising from the funded project are to be published in the following publications. All these publications have directly acknowledged the SHIAE funding support.

[1] Xiaoming Wang and Michael Y. Wang, "Band Gaps in Periodic Flexural Beams With Multi-DOF/Continuum Local Resonators," submitted to PHONONICS 2013: 2nd International Conference on Phononic Crystals/ Metamaterials, Phonon Transport and Optomechanics, June 2-7, 2013. http://phononics2013.org

[2] Michael Y. Wang and Xiaoming Wang, "Wide-Band Low Frequency Gaps in Periodic Flexural Beams With Nonlinear Local Resonators," submitted to PHONONICS 2013: 2nd International Conference on Phononic Crystals/Metamaterials, Phonon Transport and Optomechanics, June 2-7, 2013. http://phononics2013.org

[3] Michael Y. Wang and Xiaoming Wang, "Broadband Wave Attenuation in Locally Resonant Periodic Flexural Beams With Force-Moment Resonators," submitted to 25th Conference on Mechanical Vibration and Noise, ASME IDETC/CIE 2013, August 5-8, 2013. http://www.asmeconferences.org/idetc2013

Understanding Electron and Phonon Transport in Boron Carbide Nanowires for Thermoelectric Energy Conversion

Principal Investigator

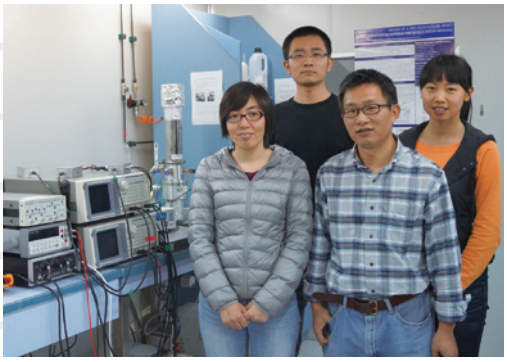
Professor Dongyan XU

Department of Mechanical & Automation Engineering, CUHK

Research Team Members

Juekuan YANG, Visiting Scholar, Shun Hing Fellow[1],
Xiaomeng WANG, Postgraduate Student[1]
Qiang FU, Postgraduate Student[1]

[1] Dept. of Mechanical and Automation Engineering, CUHK



| Reporting Period: 1 July 2012 – 30 December 2012 |

Abstract

The objective of the proposed research is to study the structure and transport property relation of boron carbide nanowires for thermoelectric energy conversion applications. Thermoelectric devices show a great potential for waste heat recovery by directly converting heat into electricity; however, to date their practical applications have been limited by their low efficiencies. Recently, several reports demonstrated significantly improved thermoelectric efficiencies by engineering thermoelectric materials into nanostructures, such as nanowires, primarily through thermal conductivity reduction. Despite boron carbides have been projected as a promising class of high-temperature thermoelectric materials, so far, no one has studied thermoelectric transport properties of one-dimensional boron carbide nanowires yet. The PI proposes to study transport properties of boron carbide nanowires for high-temperature thermoelectric applications. The approach is to integrate systematic transport property measurement on individual boron carbide nanowires and detailed structure and composition characterization for each measured wire. The ultimate goal is to develop the structure-transport property relations for boron carbide nanowires.

1. Objectives and significance

The objectives of the proposed research are

* To measure thermoelectric properties (thermal conductivity, electrical conductivity, and Seebeck coefficient) of individual boron carbide nanowires in a wide temperature range (10−800K). Since these properties are determined on the same nanowire sample, we can construct thermoelectric figure-of-merit for each boron carbide nanowire.
* To thoroughly characterize the structure and composition of each measured nanowire.
* To construct the relations between composition, structure, and transport properties of boron carbide nanowires upon the completion of the first two objectives.
* To clarify the effects of many important factors, including nanowire diameter, carbon concentration, planar defect, and doping level, on thermoelectric properties of boron carbide nanowires.

Significance: Boron carbides are promising high-temperature thermoelectric materials whose transport properties are not well understood yet especially for one-dimensional nanostructures. The proposed research will provide previously unavailable data to answer the following two fundamental scientific questions: (1) Can we correlate the structure-transport property relation of boron carbide nanowires? (2) To what extent boron carbide nanowires can enhance the thermoelectric performance compared to bulk materials? Answering these questions will not only enhance our understanding on electron and phonon transport in boron carbide nanowires but also lead to materials design rules to achieve better thermoelectric performance. The proposed study will impact technology development through providing better materials for high-temperature thermoelectric energy conversion.

2. Research methodology

To characterize thermoelectric properties of an individual nanowire, we will design and fabricate a unique microdevice as shown in Fig. 1. The device consists of two suspended silicon nitride (SiNx) membranes separated by 2 to 6 μm. A thin Platinum (Pt) resistance coil and two separate Pt electrodes are patterned on each membrane. Each resistor is electrically connected to four contact pads via metal lines on the suspended beams, enabling four-point measurement of the electrical resistance. The Pt resistor can serve as a heater to increase the temperature of the suspended membrane, as well as a resistance thermometer to measure the temperature of each suspended membrane. An individual boron carbide nanowire can be placed in between the two membranes. During the measurement, a bias voltage is applied to one Pt resistor and generates Joule heating, and accordingly increases the temperature of the heater membrane above the thermal bath temperature. Part of the generated heat will flow through the nanostructure to the other membrane and raise its temperature. The thermal conductance of the nanostructure can be determined by solving the heat transfer equation for the whole system. Then thermal conductivity of the boron carbide nanowire can be extracted after its length and cross sectional information are obtained. The four Pt electrodes on the two suspended membranes allow four-point measurements of the electrical conductivity of the nanowire and determination of its Seebeck coefficient. The thermoelectric figure-of-merit of each individual boron carbide nanowire can be determined once we measured the three fundamental transport properties.

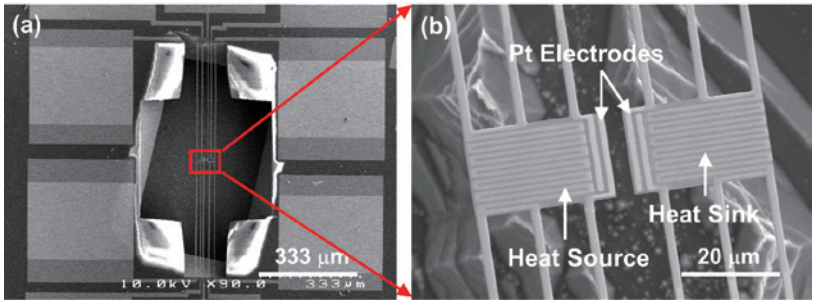


Figure 1. SEM images of the microdevice used to characterize thermoelectirc properties of an individual nanowire.

3. RESULTS ACHIEVED SO FAR

In the past six months, we have mainly accomplished the following three tasks:

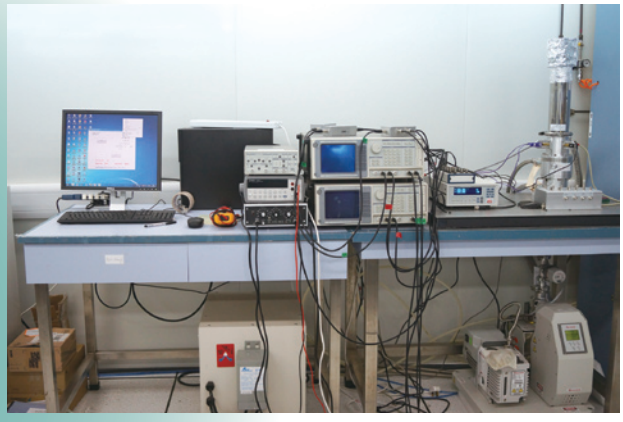


Figure 2. Experimental setup

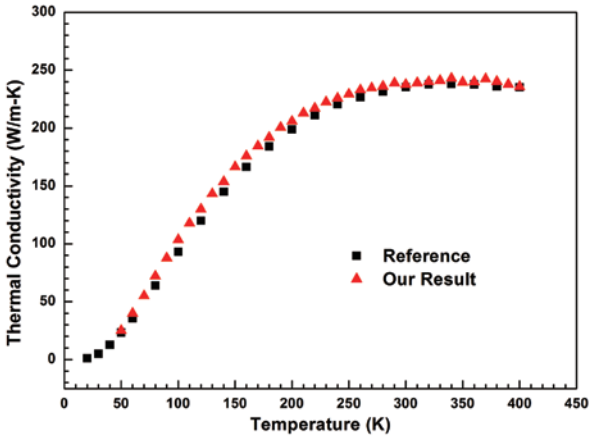


Figure 3. Thermal conductivity of an individual carbon nanotuve with a diameter of 50nm

Task 1: Design and Fabricate Microdevices

So far, we have designed and fabricated a series of suspended microdevices on silicon wafers through standard microfabrication techniques. Devices with different separations (distance between two suspended membranes) have been obtained for different applications. Before the measurement, a single nanowire or nanotube is placed across the two membranes by using a sharp probe tip under a high-magnification microscope.

Task 2: Set Up the Experimental System

We have built the experimental measurement system to characterize thermoelectric properties of a single nanowire as shown in Fig. 2. In order to reduce the heat loss during the measurement, sample is placed in a high-vacuum cryostat system. Temperature of the sample stage can be tuned between 10 K and 800 K which enables the property characterization in a wide temperature range.

Task 3: Calibrate Thermal Conductivity Measurement

To date, we have calibrated thermal conductivity measurement through our experimental setup by using relatively well-studied carbon nanotube (CNT) samples. Our experimental result (red triangle) on thermal conductivity of a multiwalled CNT with a diameter of 50 nm is given in Fig. 3 which is compared with the result in the literature (black square). As seen in Fig. 3, our result agrees well with the reference in a wide temperature range of 50 K – 400 K with a relative error less than 12%. Next, we will focus on thermal conductivity measurement of boron carbide nanowires.

Ternary Hybrid Polymer / Nanocrystal Bulk Heterojunction Solar Cells with Cascade Energy-Level Alignment

Principal Investigator

Professor Ni ZHAO

Department of Electronic Engineering, CUHK

Co-Investigator

Baoquan SUN[2]

Research Team Members

Feng WANG, Shun Hing Fellow[1],
Haihua XU, Shun Hing Fellow[1],
Ting XIAO, PhD student[1],
Mengyu CHEN, PhD student[1]

[1] Dept. of Mechanical and Automation Engineering, CUHK
[2] Institute of Functional Nano & Soft Materials, Soochow University

| Reporting Period: 1 July 2012 – 30 December 2012 |

Abstract

This proposal aims to develop ternary polymer/nanocrystal bulk heterojunction (BHJ) solar cells with cascade energy-level alignment. Semiconductor nanocrystals and polymers are attractive photoactive materials due to their solution processability, high absorption coefficient and wide spectral tunability. Hybrid solar cells combine the mechanical flexibility of polymers with the morphological stability of nanocrystals and therefore have the potential to offer superior solar cell properties. In this project we propose to create a cascade of energy levels in the photoactive layer of hybrid solar cells by utilizing a ternary BHJ structure. We will develop solution-based methods to fabricate two ternary BHJ structures, polymer/quantum dot/nanorod and polymer/nanoshell/nanorod. Their properties will be investigated via morphological, electrical and spectroscopic characterizations. The technological know-how and the fundamental understanding gained from this project will greatly benefit efforts to realize the next generation of solar cell technology.

1. Objectives and significance

1. To develop solution-based processes for scalable fabrication of ternary polymer/quantum-dot/nanorod and polymer/nanoshell/nanorod bulk heterojunction solar cells with cascade energy-level alignment.

2. To establish a versatile testing platform, consisting of spectroscopic, optoelectronic and microscopic characterization methods, with which the optimal condition for producing photovoltaic effects can be identified for various cascade hybrid systems.

3. To demonstrate high-efficiency ternary hybrid polymer/nanocrystal solar cells via a multi-pronged approach consisting of material selection, processing optimization and device design.

   The technological know-how and the fundamental understanding gained from this project will greatly benefit efforts to realize the next generation of solar cell technology.

2. Research methodology

Materials: Polymer materials will be purchased from Lumtec. Corp. The colloidal nanorods and QDs will be synthesized in solution phase. The dimensional size can be controlled by varying the reaction temperature and time, and the concentration and mixing ratio of the precursors. The nanoshell/nanorod structure can be fabricated via surface ion-exchange method. The QD/nanorod structure can be made by anchoring as-prepared QDs through molecular linkers on the nanorod surface.

Device fabrication: Solar cells will be fabricated on patterned ITO substrates. The BHJ layer will be fabricated via spin-coating; other interlayers and top electrodes will be deposited via spin-coating, sputtering or thermal evaporation.

Characterization: The morphology of the BHJ structures will be studied using atomic force microscopy and transmission electron microscopy. The current-voltage and capacitance-voltage characteristics will be measured using I-V source meters and an impedance analyzer. Spectroscopic methods, such as steady-state and time-resolved photoluminescence spectroscopy and photoinduced absorption spectroscopy, will be used to probe the charge-and energy-transfer processes in the cascade structure. Transient photovoltage and photocurrent measurement will be used to probe the charge carrier lifetime in the hybrid solar cells.

3. Results achieved so far

(1) Construction of the spectroscopic characterization platform.

We have set up the photo-induced absorption spectroscopy and charge modulation spectroscopy to study the charge separation and transport processes in the ternary BHJ system. To test our setup, we first characterized the properties of charges in a pure polymer system. Based on the spectroscopic data we were able to identify the correlation between charge localization and molecular configuration. The results are included in a recently submitted journal paper.

(2) Synthesis of ZnO nanorods and growth of nanoshell structure on ZnO nanorods.

We have synthesized ZnO nanorods with controllable aspect ratio. The relatively uniform size distribution of the nanorods was confirmed by TEM as shown in Figure 1A. We then developed a two-step ion-exchange process to grow ZnO/PbS and ZnO/Bi_2S_3 core-shell structures. Photoluminescence spectroscopy was used to investigate the impact of the shell passivation on the optical properties of ZnO. The result (shown in Figure 1B) shows that the defect emission of ZnO at ~530 nm is greatly decreased after the growth of PbS or Bi_2S_3 nanoshell, which proves that we have successfully passivated the surface defect states on ZnO nanorods by the metal sulfides. This is an important step towards reducing the charge recombination loss in the BHJ solar cells. We also note that the intrinsic emission of ZnO at ~440 nm is reduced after shell growth, suggesting that the photogenerated electrons (or holes) are partially transferred from ZnO to PbS or Bi_2S_3. How this transfer process would affect the performance of the ternary system will be investigated in the next step.

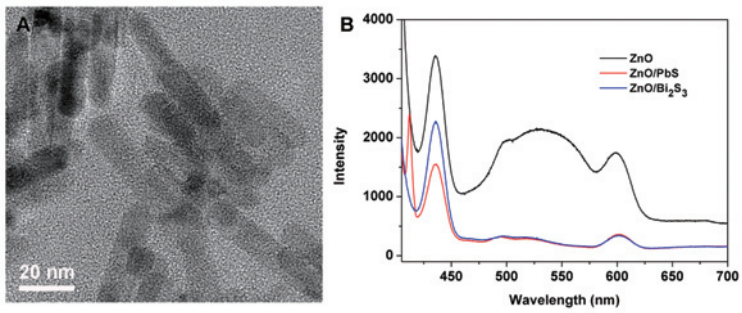


Figure 1. A) TEM image od ZnO nanrods; B) Photoluminescence spectra of ZnO, ZnO/Pbs and ZnO/Bi_2S_3 with an excitation wavelength of 380nm. The concentrations are all c.a. 0.07mg/mL.

4. Publication and awards

[1] H.H. Xu, Y.Q. Jiang, J. Li, B.S. Ong, Z.G. Shuai, J.B. Xu, N. Zhao, "Spectroscopic Study of Electron and Hole Polarons in a High-Mobility Donor – Acceptor Conjugated Copolymer", The Journal of Physical Chemistry C, under review

Biomedical Engineering Track

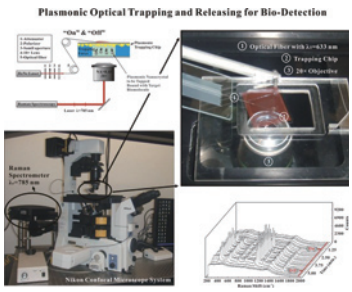
Biomedical engineering (BME) is the application of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to advance healthcare treatment, including diagnosis, monitoring, treatment and therapy.

Biomedical engineering research and development span a broad array of subfields. Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biologicals. Almost all aspects of medicine are being enhanced by biomedical engineering and healthcare technologies. Biomedical engineers are increasingly being involved with the development of novel, reliable, noninvasive technologies for the diagnosis, monitoring, and treatment of diseases. For examples, medical electronic devices and biosensors improve home/mobile healthcare; microarray technologies offer immense potential for studying the whole cellular transactions; imaging tools enhance diagnosis; robotic devices facilitate surgery and rehabilitation; and visualization and virtual reality provide excellent means for surgery training and planning.

Since 1999, the biomedical research teams in the Faculty of Engineering have acquired more than HK$75 millions supported by Hong Kong Research Grants Council, Innovation and Technology Fund, and SHIAE in related Biomedical Engineering research areas. Quite a number of significant BME projects have been carried out successfully at the Chinese University of Hong Kong. Among them are the following SHIAE supported Biomedical Engineering research projects since 2005:

» Dielectrophoresis nano-separator for precision manufacturing of polymeric nanoparticles for tumor-targeted drug delivery

» Viewing biomolecules at the right site by plasmonic tweezers and surface enhanced raman scattering



» An inexpensive functional finger prosthesis with rebounded type progressive hinge lock

» Diffusion tensor MRI predictors of cognitive impairment in confluent white matter lesion

» Lanthanide-impregnated molecularly imprinted polymer microspheres as antibody mimics on an optofluidic platform for the detection of disease biomarkers

» Signal processing strategies on cochlear implant devices for effective speech perception of tonal languages

» Terahertz probe for in vivo imaging

» Development of a robotic endoscope holder for nasal surgery

» Development of highly sensitive and large throughput surface enhanced Raman scattering (SERS) substrates for molecular diagnosis

» Research on language and brain waves

» Development of an efficient locomotion mechanism for wireless active capsule endoscope

» Bio-electromagnetic modeling and experiment setup for medical electronics RF safety assessment

» Medical applications of terahertz imaging

» Hybrid assistive knee braces with smart actuators

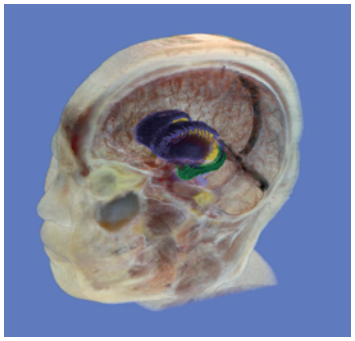
» RF radiation effect and efficiency of wireless medical devices on human body

» Photonic biosensor micro-arrays for screening of common cancers

» Cochlear implants

» Virtual anatomy and dexterous simulators for minimal access cardiothoracic and neuro-endoscopic surgeries

» Systematic synthesis of nano-informatics chips by nano-robotics manipulation



Faculty members active in the Biomedical Engineering research areas include Profs. Pheng Ann Heng and Philip Leong of Computer Science & Engineering Department; Profs. Y. T. Zhang, Max Meng, Douglas Yung, Aaron Ho, Emma MacPherson, and Arthur Mak of Electronic Engineering Department; Prof. W.-S. Liao, L.-M. Bian, L. Zhang, S.-C. Chen of Mechanical and Automation Engineering Department, and Profs. Jack Cheng, K.S. Leung, Louis Cheung, Philip Chiu, K.-P. Fung, Ling Qin, and Mary Waye of the Faculty of Medicine, among others.

Progress reports of on-going projects are given in the subsequent section while Annex 1 includes a full list of the completed research projects funded by SHIAE in the area of biomedical engineering.

Research Reports
« Biomedical Engineering »

Continuing Projects (2012)

» Dielectrophoresis Nano-separator for Precision Manufacturing of Polymeric Nanoparticles for Tumor-Targeted Drug Delivery

Continuing Projects (2011)

» Viewing Biomolecules at the Right Site by Plasmonic Tweezers and Surface Enhanced Raman Scattering

Dielectrophoresis Nano-separator for Precision Manufacturing of Polymeric Nanoparticles for Tumor-Targeted Drug Delivery

Principal Investigator

Professor Shih-Chi CHEN

Department of Mechanical and Automation Engineering, CUHK

Co-Investigator

Hsiang-Fu KUNG[2]

Marie LIN[3]

Wen Jung LI[4]

Research Team Members

Shih-Mo YANG, Shun Hing Fellow[1], Hong YAO, Shun Hing Fellow[2], Yuan TIAN[2]

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[2] Stanley Ho Centre for Emerging Infectious Diseases, Faculty of Medicine, CUHK

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[4] Department of Mechanical and Biological Engineering, City University of Hong Kong

| Reporting Period: 1 July 2012 – 30 December 2012 |

Abstract

This research aims to develop a dielectrophoresis (DEP)-based high-throughput nanoparticle separation technology that enables precise separation of polymeric nanoparticles for cancer-targeted drug delivery. Studies suggest that precise control of nanoparticles' sizes and surface charges may (1) further improve the effectiveness of the treatment and (2) reduce the related toxicity level. However, due to the solution-based nanoparticle fabrication procedure, to date there has not been any method reported in literature to precisely control the sizes and surface charges of nanoparticles for cancer-targeted treatment. In this work, we will develop a DEP-based nano-separator that is capable of collecting and separating nanoparticles according to their specific dimensions, e.g. 100nm ± 10nm, and surface charges. PEI-CyD-FA mediated polymeric nanoparticles, a promising new cancer-targeting drug developed by our team, will be used in the DEP device for separation. We will then perform in vivo mouse studies with the separated polymeric nanoparticles in order to investigate and characterize the level of improvements in terms of cancer-targeting sensitivity and toxicity control.

1. Objectives and significance

The overall goal of the proposed research is the development of four DEP nano-separator devices that can be used to separate and collect polymeric nanoparticles of various sizes. High-throughput nanoparticle separation at the speed of 3 ml/min will be demonstrated via the DEP nano-separators, enabling the precision control of nanoparticles size distribution, ranging from 50 nm to 300 nm. We will perform in vivo studies using an orthotropic hepatocellular carcinoma (HCC) mouse model. Polymeric (H1) nanoparticles will be used to target the somatic tumor in mice. The level of improvements in terms of cancer-targeting sensitivity and toxicity control due to different nanoparticle size distribution will be determined.

Application of the developed DEP-separation technology to nanomedicine and pharmaceutical industry will generate significant impact in the following ways: (1) more precise and specific drug targeting and delivery, (2) reduction in toxicity while improving therapeutic effects, (3) greater control of safety and compatibility, and (4) realization of low cost, high-precision pharmaceutical and medicine manufacturing.

2. Research methodology

1. Model, design and fabricate high-throughput DEP nano-separators optimized for nanoparticle separation.
2. Fabricate and characterize polymer nanoparticle with DEP nano-separator:
   >Prepare the polyplexes of H1/pDNA including H1 synthesis, plasmid expansion and polyplexes formation.
   >DEP separation method: Mix DNA and H1, N(H1) /P(pcDNA)= 20/1 in 2.5% glucose solution, standing for 10 min. Let polyplexes pass through DEP chip under four voltage and frequency conditions for nano-particle collection. Wash DEP chip without electric field and collect the blocked polyplexes from the outlet.
   >Characterization of the quantity, particle size and zeta potential of both the passed and blocked polyplexes.
   >Determine transfection efficiency of the polyplexes on 293T cells by observing the quantity of EGFP positive result in cells after 24 hours.
3. Perform in vivo mice study to investigate the efficacy of the separated polymeric nanoparticles.

3. Results achieved so far

The project has been progressing well and hitting all the milestones. Based on our parametric model, we have designed and fabricated several DEP nano-separators optimized for polymer nanoparticle (H1/pDNA polyplexes) separation. Figure 1A shows the image of a recently fabricated DEP device; Fig 1B shows the zoom-in view of the electrodes in the microchannel that generate the AC electric field for particle trapping.

As shown in Fig. 2A, the results of our nanoparticle separation experiments indicate that the size of the separated particles was well controlled with a narrow distribution (σ = 10 ~ 50 nm); this validates that our physical model is correct and the fabricated DEP devices can effectively block both particles of smaller and larger sizes; this is attributed to the combined effects of the nonuniform electric field distribution on the H1/pDNA polyplexes and its interaction with the nonuniform AC electric field generated by the DEP device.

Before the animal experiments, we used the separated polyplexes to treat the cells in vitro in order to verify their effectiveness will not be affected by the DEP separation procedure (Transfection dose: 40 μL/well on 293T cells for 24 hours). The results from the cells, shown in Fig 2B, indicate our H1/pDNA polyplexes has good transfection efficiency after passing through the DEP nano-separator. We expect the separated polyplexes to have reduced toxicity and enhanced transfection efficacy in general. These hypotheses will be verified in the near future when they are used to treat mice.

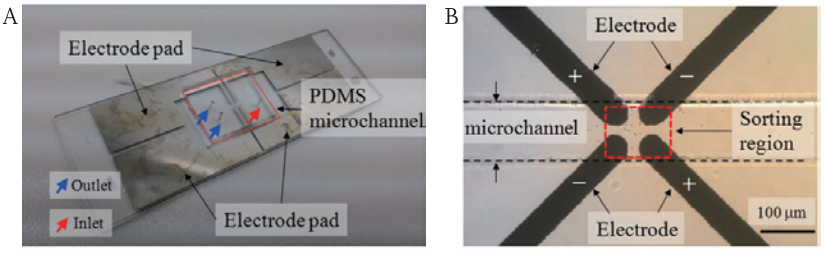


Figure.1: (A) DEP nanoparticle sorting chip; (B) Optical image of electrodes and microchannel.

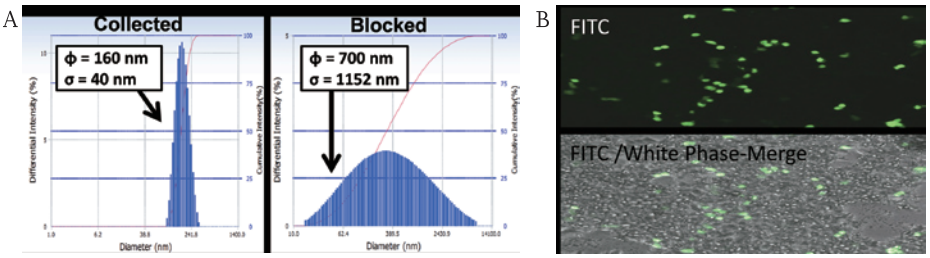


Fig.2 (A) Particle size distribution characterized for both collected and blocked solution; (B) fluorescent image of cells treated with DEP filtered nanoparticle, indicating decent transfection efficiency.

Viewing Biomolecules at the Right Site by Plasmonic Tweezers and Surface Enhanced Raman Scattering

Principal Investigator

Professor JB XU

Department of Electronic Engineering, CUHK

Co-Investigator

H.C. ONG[2]

H.P. HO[1]

Research Team Members

H.X. ZHANG, Research Assistant[1]

[1] Dept. of Electronic Engineering, CUHK

[2] Dept. of Physics, CUHK

| Reporting Period: 1 July 2011 – 30 December 2012 |

Abstract

In this reporting period we have explored novel plasmonic nano-optical tweezers (PNOTs) systems for optical nano-trapping and nano-manipulation, and demonstrated the use of PNOTs for on-chip detection of molecules within a microfluidic platform.

1. Objectives and significance

With surface plasmons, the scaling of all-optical trapping and manipulation from μm to nm level can be easily achieved. Here we have developed several novel plasmonic nanostructures and demonstrated their capabilities for effectively optical trapping of nano-objects in near-field and for optical manipulation of target objects entirely in the nanoscale regime. The nano-manipulation issue is very challenging and significant because it is not only breaks the diffraction limit of light, but also realizes controllable movements in the nanoscale with optical radiation. Furthermore, we have combined the use of PNOT and surface-enhanced Raman scattering (SERS) to demonstrate the possibility for reproducible molecular detection. Our approach provides the advantages of low fabrication cost, rapid detection, multifunctional operation, and ease of implementation in common microfluidic lab-on-a-chip platforms.

2. Research methodology

2.1 Theoretical simulation: 2D and 3D finite-difference time-domain (FDTD) modeling.

2.2 Optical force calculation: Maxwell stress tensor (MST) method.

2.3 Device fabrication: electron beam lithography, nanoimprint technique, physical vapor deposition (PVD).

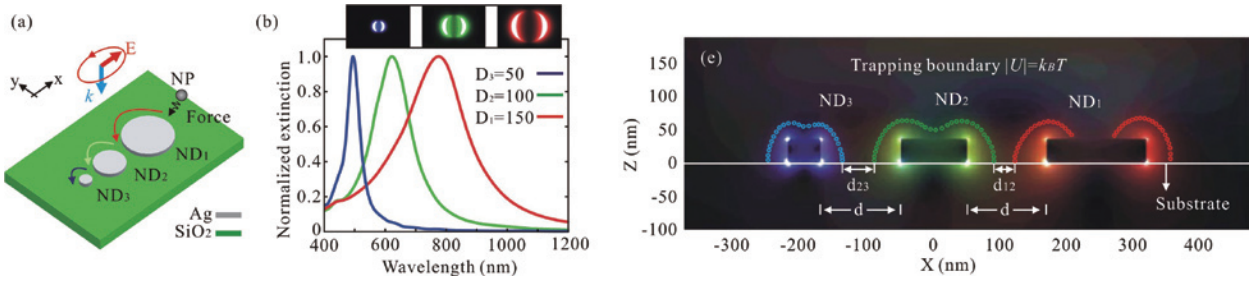
2.4 Characterization: AFM, SEM, TEM, Hitachi U-3501UV-visible/NIR spectrophotometer, Deltanu Examine R modular Raman system, Nikon confocal microscope.

3. Results achieved so far

3.1 We have developed a double-layered metal nano-strips system for sensing applications. Our results reveal that the device exhibits a refractive index sensitivity of ~200 nm/RIU, and a maximum surface enhanced Raman scattering (SERS) factor of 10^9-10^{10} from metallic NPs trapped in the near-field region [1].

3.2 The feasibility of using gold nano-ring as PNOT is investigated. We found that at resonant wavelength of 785 nm the nano-ring produces a maximum trapping potential of ~$32k_BT$ on gold nanoparticles (Au-NP). The existence of multiple potential wells results in a very large active volume of ~10^6 nm^3 for trapping the target particles. Such large active volume is very attractive for low concentration operation [2].

3.3 We explored an all-optical nano-manipulation scheme based on plasmonic nano-disks (NDs) with graded diameters [Fig. 1(a) and 1(b)]. Our results indicate that the target experiences a trapping potential strength of 5000 kBT/W/μm^2, maximum optical torque of ~336 pN•nm/W/μm^2, and the total active volume reaches ~106 nm^3. By switching the wavelength and polarization of the excitation source, target nano-particles trapped by the device can be manipulated from one ND to another one arbitrarily [Fig. 1(a) and 1(c)] [3].



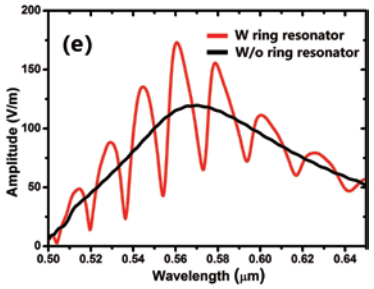


Fig. 1. (a) Schematic of the all-optical nano-manipulation. (b) Normalized extinctions of ND_1, ND_2, and ND_3. The top inset shows $|E|^2$ distributions at resonances for each ND. (c) Trapping boundaries for ND_1, ND_2, and ND_3, respectively, with d=120 nm and incident power density of 1 mW/μm^2. (d) Schematic of the PNOT-resonator system. (e) Resonance splitting in the PNOT-resonator system comparing with isolated PNOT.

3.3 We explored a PNOT-resonator scheme [Fig. 1(d) and 1(e)]. The PNOT (nano-antenna) is set in the gap of a macro-ring resonator. Our initial simulation results indicate that the resonance splitting will occur in the PNOT-resonator system, and hence with much higher trapping force and sensitivity comparing with isolated PNOT. The linking of the micro/nano-resonators can open up new opportunities for more efficient lab-on-chip plasmonic trapping and sensing [4]. This hybrid photonic structure is also of unique optical properties. [5]

3.4 We demonstrated the use of PNOT and SERS for reproducible and low concentration of molecular detection. The gold nano-island substrate (Au-NIS, λ_R=632.8 nm) acts as PNOT. The targets are silver nanodecahedrons (Ag-NDs, λ_R=475 nm) that has been bound with target molecules [Fig. 2(a) and 2(b)]. The Au-NIS becomes active upon receiving He-Ne laser radiation, thus trapping the targets into the

hot-region. This can be characterized through the enhanced Raman signals. Removing the He-Ne laser will lead to the release of target [Fig. 2(c)]. Therefore another round of detection can be re-started again, after rinsing the sample and injecting of another batch of target molecules [6].

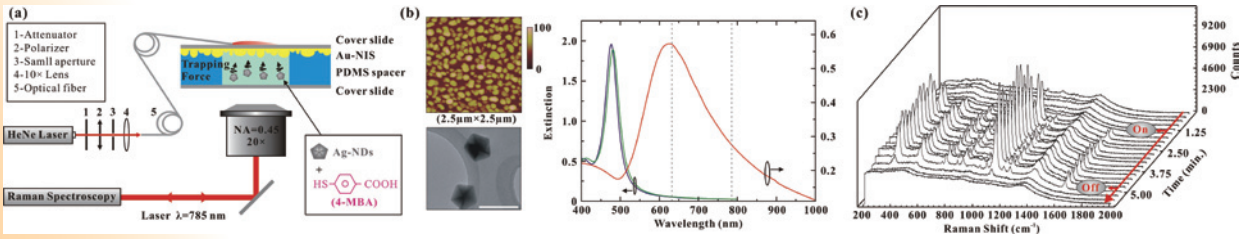


Fig. 2. (a) Schematic of the reproducible bio-detection platform. (b) AFM image of Au-NIS, TEM image of Ag-NDs, and extinctions of them. (c) Temporal Raman spectra showing the trapping and releasing processes.

3.5 We explore surface plasmon resonance (SPR) microscope to image low-index submicron dielectric nanoparticle as its size and refractive index imitate single virus (e.g. H5N1 influenza) very well [7]. By making use of the depolarization of the surface plasmon upon scattering of the nanoparticle, silica nanoparticle with diameter smaller than 150 nm is imaged by polarization- and phase-resolved detection schemes. Fig. 3(a) and (b) show the phase contrast and orthogonal polarized and phase contrast images of 140 nm nanoparticle anchored on 50 nm Au film being excited by He-Ne laser. The extractions are shown in Fig, 3(c), demonstrating high image contrast.

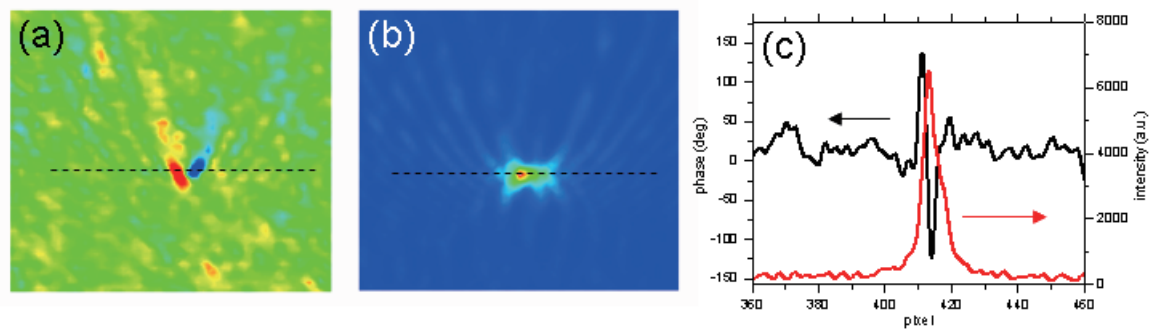


Fig. 4. (a) Phase and (b) polarization resolved images of 140 nm diameter silica nanoparticles. (c) The extractions from (a) and (b) show good contrast.

3.6 We demonstrate phase-based SPR sensor with supreme performance [8]. Within the framework of coupled mode theory, we optimize the phase jump of surface plasmon resonance and obtain the figure-of-merit close to 2000/RIU, which is the highest reported to date. Fig. 4(c) shows the binding of bovine serum albumin antibodies (anti-BSA) to BSA-coated Au periodic array by using conventional and phase methods. Apparently, the phase-based detection in Fig. 4(a) outperforms the conventional counterpart (Fig. 4(b)) is clearly recording the binding event of anti-BSA and the washing by NaOH. On the other hand, the conventional detection does not any appreciable shift of wavelength, indicating its ineffectiveness in this case.

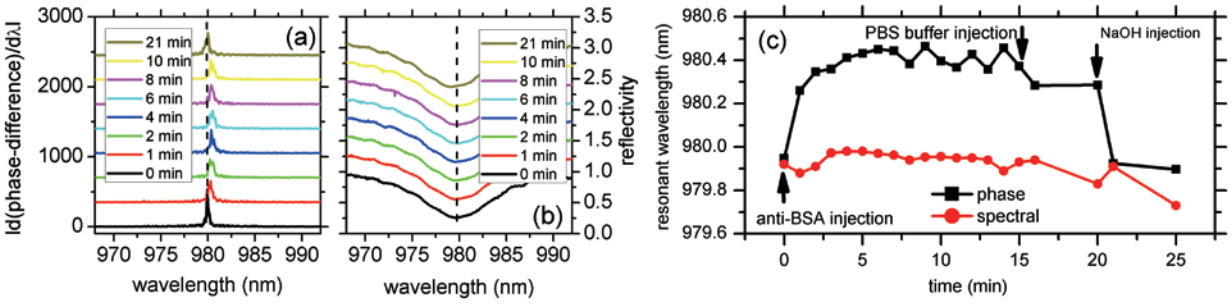


Fig. 4. (a) Temporal SPR peaks showing the binding of anti-BSA and the washing by NaOH. (b) Temporal SPR sips by conventional method under the same condition. (b) Plot of resonant peak positions as a function of time by using (a) and (b) detection schemes.

4. Publication and awards

[1] Z.W. Kang, H.X. Zhang, H.F. Lu, and H.P. Ho, "Double-layered metal nano-strip antennas for sensing applications," Plasmonics DOI 10.1007/s11468-012-9388-7 (2012).

[2] Z.W. Kang, H.X. Zhang, H.F. Lu, J.B. Xu, H.C. Ong, P. Shum, and H.P. Ho, "Plasmonic optical trap having very large active volume realized with nano-ring structure," Optics Letters 37, 1748-1750 (2012).

[3] Z.W. Kang, H.X. Zhang, H.F. Lu, J.J. Chen, and H.P. Ho, "Graded plasmonic nano-disks for near-field nano-manipulation," Optics Letters (Submitted, 2013).

[4] H.X. Zhang, Z.W. Kang, H.F. Lu, J.J. Chen, J.B. Xu, H.C. Ong and H.P. Ho, "Linking micro/nano-resonators for efficient plasmonic trapping and sensing," (in preparation, 2013).

[5] H.X. Zhang, Z.W. Kang, H.F. Lu, J.J. Chen, J.B. Xu, H.C. Ong and H.P. Ho, "Tailoring the quality of plasmonic resonance within micro-resonator," (in preparation, 2013).

[6] Z.W. Kang, H.F. Lu, J.J. Chen, H.X. Zhang, J.B. Xu, H.C. Ong and H.P. Ho, "Plasmonic nano-optical trapping and releasing for reproducible bio-detections," Applied Physics Letters (in preparation, 2013).

[7] Y.P Lam, L.Y. Yiu, C.F. Chan, and H.C. Ong, "Amplitude and phase imaging of dielectric nanoparticles by using surface plasmon resonance microscopy," (to be submitted).

[8] S.L. Wong, L. Zhang, S.Y. Wu, H.P. Ho, and H.C. Ong, "High performing phase-based surface plasmon resonance sensors by decay rate matching," (to be submitted).

Multimedia Technologies Track

We are living in an exciting era that benefit from the rapid changes being unleashed by the Internet and the information technology. Armed with more computational power and faster communication networks, scientists and engineers can now create more exciting applications and services to end users. Some of the applications or services that we thought only exist in the science-fiction movies are now within grasp and may become reality within this decade.

Multimedia technologies constitute a multi-disciplinary field that extends beyond engineering to reach disciplines such as arts, sciences and humanities. Main contributive areas include engineering, computer science, artificial intelligence, communications, design, ergonomics and human factors, cognitive psychology, linguistics, and philosophy. The impact of multimedia applications is tremendous – it ranges from medicine to entertainment; from bridging the societal digital divide to remote space exploration. In short, our imagination is the limit.

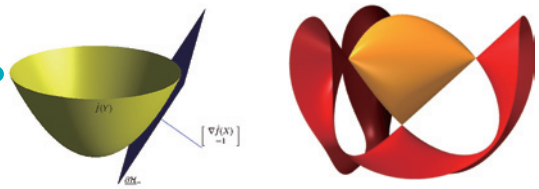
At the Faculty of Engineering, many professors and students are dedicated to advancing the frontiers of multimedia technology. One can easily find a plethora of relevant research projects and home grown technologies that can benefit different types of end users and companies. The research teams have acquired more than $84 million from the Industry Support Fund and Innovation and Technology Fund over the past decade to support various kinds of multimedia research and development projects, a strong indication of the strength, as well as our commitment in this important area.

"What does the future hold with these advanced multimedia technologies?" A question usually put forth by end users. Rather than making a futuristic projection, researchers and scientists in CUHK prefer the practical approach taken by Dr. Alan Kay, a Turing award winner, who said: "*the best way to predict the future is to invent one*". We strongly believe that it is an exciting journey that will vastly improve the way to look and process information in the coming decades, and we hope that interested parties can join us in this endeavor. Currently, we are working on interesting topics including:

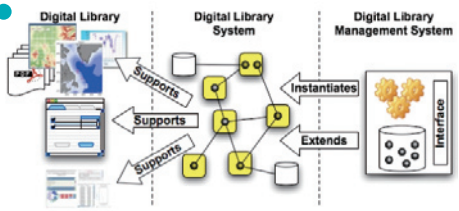
1. Audiovisuals: photorealistic graphical animation, multilingual speech recognition and synthesis, avatars, information retrieval from mixed-language spoken documents, video segmentation and tracking, face recognition.

Image Smoothing

2. Communications: multimedia networking, compression, wireless communication, multimedia content distribution via satellite-terrestrial networks, capacity enhancement of wireless communication, P2P-live streaming systems, time-critical control of shared networks.

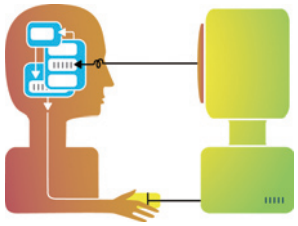


3. Digital Libraries: content-based image, video and audio retrieval, information visualization, cloud storage and computation systems, semantic analysis for image resizing.



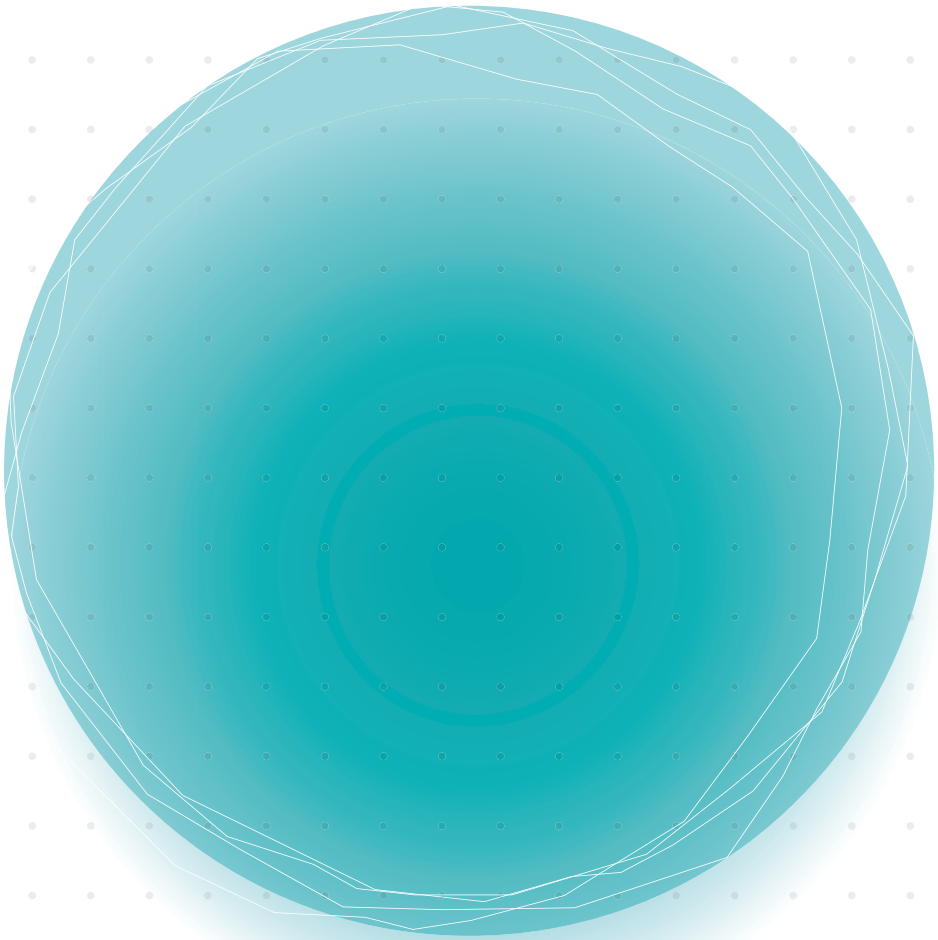
4. Games: three dimensional game engines, mobile and multi-player games with parallel rendering methods.

5. Human-computer interaction: human-centric, mobile and multimodal interfaces, human-robot interaction, wearable computing, virtual reality, augmented reality, biometrics-secured computing, Pattern Computation for Compression and Performance Garment.



Faculty members active in the area of Multimedia include Prof. Patrick P.C. Lee, and Prof. John C.S. Lui of Computer Science & Engineering Department; Prof. King Ngan, and Prof. Tan Lee of Electronic Engineering Department; Prof. WS Wong, Prof. Raymond Yeung, Prof. Jack Lee and Prof. Dah-Ming Chiu, Prof. Xiaoou Tang and Prof Sidharth Jaggi of Information Engineering Department; Prof. Ronald Chung, Prof. K.C. Hui and Prof. Charlie Wang of Mechanical and Automation Engineering Department and Prof. Helen Meng and Prof. Anthony So of Systems Engineering & Engineering Management Department.

Progress reports of the on-going projects are given in the subsequent section while Annex 2 includes a full list of completed research projects funded by SHIAE in the area of multimedia technology.



Research Reports

« Multimedia Technologies »

Continuing Projects (2012)

- Face Recognition Across Ages Through Binary Tree Learning

Continuing Projects (2011)

- Semantic Analysis for Image Resizing
- Time Critical Applications over a Shared Network
- Amplify-and-forward Schemes for Wireless Communications

Face Recognition Across Ages Through Binary Tree Learning

Principal Investigator

Professor Xiaoou TANG

Department of Information Engineering, CUHK

Research Team Members

Zhifeng LI, Associate Prof.[1]

[1] Shenzhen Institute of Advanced Technology

| Reporting Period: 1 July 2012 – 30 December 2012 |

Abstract

Children faces change much faster over time than adult faces, making it much more difficult to process by traditional face recognition algorithms. Unfortunately, researches on age invariant face recognition has been sparse and even the state of the art results are poor on children face recognition across different ages. In this project, we focus on this fundamental research problem. We propose an age invariant face recognition approach that reduces age variation gap between two age groups. By separately processing the texture and shape features, the algorithm is robust to both profile and texture variation over large age gaps. The algorithms developed here can be applied to a wide range of real world applications, including face verification using ID photos with age gaps, digital family photo-album management with photos ranging from childhood until adult years. More importantly, the algorithms developed in this project are critical in meeting a recent urgent need of finding missing children on the internet.

1. Objectives and significance

In this project, we focus on a fundamental research topic: age invariant face recognition. It has been shown that the recognition tasks for children faces are much harder than for adult faces. This is mainly because children face profiles undergo larger variations over even a short period of time. The state of the art age invariant recognition algorithms achieve only 40% equal error rate on the FGNET database. To address these challenges, we propose a new age invariant face recognition algorithm.

The algorithms developed here can be applied to a wide range of tasks. For example, for face verification using ID photo, usually the ID photo is taken long ago (national ID card in China is valid for 20 years), therefore age variation is a significant factor. For digital family photo-album management application, photos may range from childhood until adult years, thus requires age invariant face recognition algorithms. This project is also inspired by a recent urgent need of finding missing children on the internet. To address this challenge, we try to apply

face recognition technology. However, we found that children faces change rapidly over time and there are few existing algorithms that achieve satisfactory performance on age invariant face recognition for children faces. In this project, we propose a couple of new age invariant face recognition algorithms based on new machine learning approaches.

2. Research methodology

Traditional age invariant recognition approaches can be categorized into two groups, age modeling based methods and discriminative learning methods. The age modeling methods try to reduce age variation at the preprocessing stage. The discriminative learning methods try to reduce age gap after the face features are already extracted. Neither approaches work well so far. In this proposal, we propose a novel approach that reduces age variation gap between two age groups at the feature extraction stage directly through joint encoding learning. For the coupled coding tree to work well over large age gaps, we need to align the faces reasonably well across age groups. Facial aging is a complex process that involves changes in face profiles, facial components geometry, facial fat, winkles, facial hair, and scars. We notice that all these changes can be categorized into two basic types of change, shape and texture. When they are blended together, it is difficult for any method to work well. So for the coupled coding to work well, we propose to separate shape and texture and process them separately.

We also propose a novel approach to address the representation issue and matching issue in age invariant face recognition. In this framework, we first develop a new local descriptor called learning based local binary pattern (LLBP) to encode the micro-structure of the facial images into a set of discrete codes by incorporating a learning based encoding method. The code histogram of the LLBP descriptor is more uniformly distributed than the original LBP descriptor, which means more informative and discriminative. By densely sampling the LLBP descriptor over the entire facial image, sufficient discriminant information can be extracted for further analysis. Since LLBP-based local features span a high-dimensional feature space, to avoid the over fitting problem and improve the recognition performance, we further develop a new subspace learning algorithm called cascade discriminant analysis to refine this feature space.

3. Results achieved so far

We have developed two new algorithms for cross modality face recognition. Experimental results on MORPH dataset (the largest face aging dataset available in the public domain) clearly show the effectiveness of our approach over the state-of-the-art. Two papers have been submitted and are currently under review.

4. Publication and awards

[1] Z. Li and X. Tang, "Mutual Component Analysis for Photo-Sketch Face Recognition," under review for IEEE Conf. on Computer Vision and Pattern Recognition, 2013.

[2] D. Gong, K. Zhu, and Z. Li, "Learning Based Local Binary Pattern and Cascade Discriminant Analysis for Age Invariant Face Recognition," Submitted ICASP 2013

Semantic Analysis for Image Resizing

Principal Investigator

Professor TT WONG

Department of Computer Science and Engineering, CUHK

Research Team Members

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Linling ZHANG, Postdoc[1],
Xueting LIU, PhD student[1],
Kin Chung KWAN, PhD student[1],
Wuyao SHEN, PhD student[1],
Xiangyu MAO, MPhil student[1]

[1] Dept. of Computer Science & Engineering, CUHK

| Reporting Period: 1 July 2011 – 30 December 2012 |

Abstract

With the wide popularity of portable display devices, images are often visualized through small displays of various resolutions and aspect ratios. On the other hand, images are typically captured for large display. Naive image resizing results in over-squeezing of prominent content and loss of details. However, the definition of saliency is usually vague and based on the low-level image features that may not be related to the semantics.

Although high-level semantics analysis (such as automatic recognition of arbitrary objects) is infeasible in the near future, analysis of certain middle-level semantics, such as symmetry and foreshortening, is feasible. In this project, we propose a semantics-aware retargeting framework. Based on the detected semantics, the image can then be retargeted in a more sensible way that preserves the detected semantics. Knowing the semantics not only allows us to resize images and videos more intelligently, but also opens up a new space for retargeting. This new space of cell-by-cell processing provides much flexibility to avoid over-squeezing, over-stretching, and undesirable bending of prominent symmetric structure.

Understanding cells is probably only the first step towards high-level semantic understanding. To further understand the structure these cells form, we plan to approach this challenging semantic analysis problem based on the Gestalt principles of human visual perception. By solving these challenges, we believe the outcome (the knowledge, publications, and algorithms) from the proposed project should motivate further study along the direction of semantics-aware resizing by the community. Besides the developed algorithm should be directly applicable in mobile computing and movie production.

1. Objectives and significance

The wide availability and popularity of small portable display devices leads to an important display problem, as movies are normally produced in specific resolutions and aspect ratios (4:3 or 16:9). Adaptation is needed for the transition from the legacy 4:3 television to 16:9 HDTV broadcasting, as most legacy videos are not produced for HDTV. Simple scaling for small display may lead to over-squeezing of prominent content and poor visualization. The major challenge of resizing is on how to define the importance. Existing importance metrics rely on low-level image features, which may not correspond to the true semantics.

While computational understanding of general image semantics is infeasible in the near future, detection of middle-level semantics, such as symmetry and foreshortening, is feasible. They can drastically improve the retargeting. For instance, by identifying the symmetry pattern in an image of architectural buildings, image can be retargeted to a smaller display by removing the repeated windows (cells) of the buildings. This means we can "summarize" the repeated content and avoid the blurry result caused by naive image downsampling. We believe by understanding one more piece of semantics, we can open an extra space for image resizing. The long-term significances and impacts of this project are:

Significance-1: The developed method should be directly applicable to mobile computing and movie production. Legacy images can be automatically retargeted to small display on portable devices as well as HDTV.

Significance-2: As semantics analysis is a novel direction in retargeting, we believe the research publication and algorithms produced will motivate the graphics community and inspire future work.

2. Research methodology

We first tackle one common type of symmetry, the translational symmetry. Existing symmetry analysis methods unfortunately are usually slow for interactive retargeting applications. Instead, we shall propose a real-time and automatic method to detect the symmetry over content with more respect to the semantics. In addition, we can smooth the transformation and intensity of cells across the lattice. So that we can maintain the visual seamlessiness over the retargeted lattices, in terms of both geometry (image-space) and illumination.

The first step is to locate the potential cells that form the lattice. Note that we try not to make any assumption on cells and the number of lattices. Our plan is to evaluate the region-based feature detection and identify the most stable one. We may propose a novel region-based feature detection method if none of them is stable enough. The notion of Gestalt (form in German) is very well-known and widely used in various fields. The well-known Gestalt laws by Wertheimer reflect strategies of the human visual system to group objects into forms and create internal representations for them. In this project, we plan to analyze the semantics in the given image by explicitly applying Gestalt grouping laws computationally. We plan to use a subset of these Gestalt laws for grouping subtle image details and hence summarize the image content. We then evaluate the correctness of the proposed method by applying the proposed algorithm on multiple test cases and measuring its correctness comparing to the ground truth. An appropriate evaluation is the user study. The user study shall be conducted in comparing to various state-of-the-art retargeting methods. Another important evaluation is the system throughput.

3. Results achieved so far

So far, we have developed a prototype image retargeting system. It first extracts the potential cells using MSER, and then constructs the potential lattices. Once lattices are estimated, the system can resize the images using cell-by-cell deletion or insertion. Figure 1 compares our result (e) to existing image retargeting methods. It shows that our method can better preserve the overall structure (of the building in this case) in (a) while achieving the goal of resizing without clipping the building as in (b). The result confirms that understanding more semantics can better (and meaningfully) solve the retargeting problem.

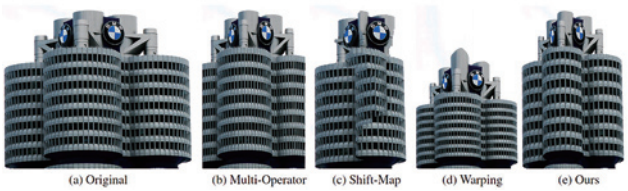

Figure 1: Comparison of our result to that of existing image resizing.

Figure 2: Reducing the size of Taj Mahal.

However, lattices are just one case of cell grouping. Cells/elements can be grouped into various human recognizable structures or forms (gestalts). To achieve this goal, we formulate our gestalt formation as a graphcut problem. Figure 3 shows our grouping results in multiple cases based on the gestalt laws of regularity and proximity, as well as the shape similarity. With the gestalts (groups), we can perform retargeting by abstraction and summarization. Figure 3 shows our result.

So far, our work and related algorithms have been published in two ACM SIGGRAPH papers (the most prestigious graphics conference, and the venue is so prestigious that all papers are simultaneously published as journal articles in ACM Transactions on Graphics), and two other papers.

4. Publication and awards

[1] X. Yang, L. Zhang, T.T. Wong, P.A. Heng, "Binocular Tone Mapping," ACM Transactions on Graphics (SIGGRAPH 2012 issue), Vol. 31, No. 4, July 2012, pp. 93:1-93:10.

[2] L. Nan, A. Sharf, K. Xie, T.T. Wong, O. Deussen, D. Cohen-Or, and and B. Chen, "Conjoining Gestalt Rules for Abstraction of Architectural Drawings," ACM Transactions on Graphics (SIGGRAPH Asia 2011 issue), Vol. 30, No. 6, December 2011, pp. 185:1-185:10.

[3] W. Feng, L. Wan, Z. Lin, T.T. Wong and Z.Q. Liu, "Perceptual Thumbnail Generation," Perceptual Digital Imaging: Methods and Applications, Edited by R. Lukac, CRC Press, 2013, pp. 193-221.

[4] H. Wu, T.T. Wong and P.A. Heng, "Parallel Structure-aware Halftoning," Multimedia Tools and Applications, 2012, to appear.

Time Critical Applications over a Shared Network

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| Reporting Period: 1 July 2011 – 30 December 2012 |

Abstract

Interest in networked control systems has grown rapidly as many novel applications have been identified such as remotely controlling a network of mobile sensors. These new applications can ultimately lead network applications into a new era. In time-critical networked control applications, feedback and control information to be transmitted necessitates a new type of multimedia data traffic on a network. Different from standard real-time video and audio data, time critical data traffic can tolerate only low bit error probability and bounded delays. Controlling multiple dynamical systems through a shared network can provide significant efficiency improvement and development cost reduction. This project investigates the close relationship between control and communication as exemplified by remote control of time-critical dynamical systems over a shared communication network. One key issue to address for a shared network is to schedule network resources to accomplish various control tasks. In the project, two configurations are considered, that is, one master multiple slave configuration and multiple master multiple slave configuration. A time division multiplexing (TDM) scheme was utilized in the case of first configuration. For the more challenging scenario consists of multiple independent controllers, protocol sequence based MAC protocol was deployed. In the controller node, Kalman-based approach was considered to compensate for data packet loss in network transmission. Two platforms were developed to enhance the practicality of the fundamental research. A testbed was developed including three pendulum-cart systems remotely controlled by one or three embedded controllers. To study communication and control issues for networked intelligent agents, we also developed a platform consisting of a micro unmanned aerial vehicle (UAV) and an unmanned ground vehicle (UGV).

1. Objectives and significance

This project aims to investigate the close relationship between control and communication as exemplified by remote control of time critical dynamical systems over a shared communication network.

A fundamental research question is to address the real-time scheduling of network resources for these different types of traffic in order to accomplish various control tasks. To enhance the practicality of the fundamental research, it is essential that experimental platforms be established so that various communication protocols can be tested and compared.

2. Research methodology

In the project, two configurations are considered, that is, one master multiple slave configuration and multiple master multiple slave configuration. A time division multiplexing (TDM) scheme was utilized in the case of first configuration. For the more challenging scenario consists of multiple independent controllers, protocol sequence based MAC protocol was deployed to moderate the access of simultaneous systems in an efficient manner. Efficient data fuse algorithms integrating separate sensors were considered to obtain optimal system states estimation. Kalman-based approach was considered in the control node to compensate for data packet loss in network transmission.

3. Results achieved so far

(1) The issues of control and communication of multiple plants over a shared wireless network were explored via studying stabilizing and tracking control of multiple pendulum-carts by one or multiple remote controllers. Time division multiple (TDM) based MAC protocols, state estimators and control laws were proposed. A testbed shown in Fig. 1 was developed consisting of three pendulum-cart systems remotely controlled by one or three independent embedded controller. Experimental results validate that the multiple pendulums can be stabilized while the carts accurately track the desired trajectories.

(2) The idea of protocol sequence was applied to arbitrate access to the shared wireless network. In particular, the Generalized Prime Sequences (GPS) based MAC protocol with acknowledgement (ACK) was developed. It is shown that the GPS based protocol significantly outperforms the π-persistent RA MAC scheme with respect to the probability of packet loss. Using the control packets received at the plant as ACK, the performance of the GPS and RA based MAC protocols can be highly improved. A heuristic and computationally efficient estimation and control scheme was considered. Numerical results illustrate that the cost performance of the GPS based NCS is much better than that of the π-persistent RA based NCS.

(3) To investigate communication and control issues for networked intelligent agents, the coordination of aerial-ground robots was considered. We presented a visual-based approach to achieve cooperation between a micro UAV and a UGV using a single onboard camera. The UAV can autonomously track and land on the moving UGV by detecting and locating the landing target on the UGV. The images captured by the onboard camera are transmitted to the land laptop over wireless channels. The laptop estimates the relative position from the received images, and transmits the estimated position to the UAV over wireless channels. Practical experiments show that the UAV can successfully achieve autonomous taking off, tracking and landing on the moving UGV via the proposed vision-based approach. The developed platforms are shown in Fig. 2.

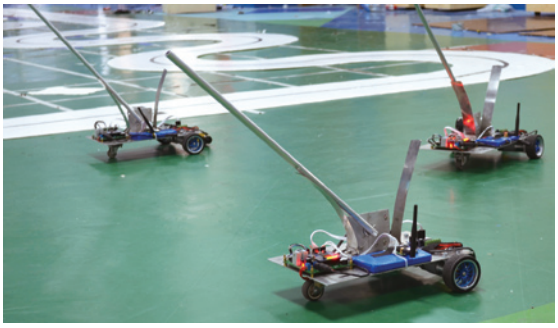

Fig. 1. The remotely controlled pendulum-carts.

Fig. 2. The quadrotor UAV and the UGV platforms.

4. Publication and awards

[1] H. Cheng, Y. S. Chen, W. S. Wong, Q. Yang, L. F. Shen and J. Baillieul, "Stabilizing and Tracking Control of Multiple Pendulum-Cart Systems over a Shared Wireless Network," the 31st Chinese Control Conf., pp. 5849-5854, July 2012, Hefei, China.

[2] H. Cheng, Y. Chen, W. S. Wong, Q. Yang and L. F. Shen, "Protocol Sequence Based Wireless Media Access Control in Neworked Control Systems," the 12th Int. Conf. on Automation, Control, Robotics and Vision, pp. 707-712, Dec. 2012, Guangzhou, China.

[3] H. Cheng, Y. S. Chen, X. K. Li, W. S. Wong and L. F. Shen, "Autonomous Takeoff, Tracking and Landing of a UAV on a Moving UGV Using Onboard Monocular Vision," submitted to the 31st Chinese Control Conf., July 2013.

[4] Yi Wu, Kenneth W. Shum, Wing Shing Wong, Qian Su, and Lianfeng Shen, "Safety Messages Broadcast in Vehicular Ad Hoc Networks Based on Protocol Sequences," submitted for publication.

Amplify-and-forward Schemes for Wireless Communications

Principal Investigator

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| Reporting Period: 1 July 2011 – 30 December 2012 |

Abstract

This project considers the problem of low-complexity and high throughput schemes that can robustly and securely communicate in the presence of noise (random noise or adversarial jamming) over wireless networks.

1. Objectives and significance

Throughput and robustness/security are two primary considerations in the design of high-capacity public wireless networks. These have to be traded off with each other – higher robustness requires more redundancy. Adding in the desirable design constraint of low-complexity algorithms that can be "easily implemented" makes the overall design of algorithms attaining such performance highly challenging.

The goals of this project are to:

(a) Characterize information-theoretic bounds on the maximal throughput obtainable in wireless networks via low computational complexity methods.

(b) Design algorithms that attain performance meeting such bounds.

2. Research methodology/ Results achieved so far

We considered various theoretical and algorithmic tools for this problem:

1. Coding theory for wireless networks: We were able to use theoretical tools from "classical" point-to-point communication channels to characterize upper and lower bounds on the throughput attainable in networks even when worst-case jamming occurs. In particular, we were able to demonstrate network analogues of the classical Hamming upper bound on the capacity, and code constructions analogous to the classical "Gilbert-Varshamov code construction". These bounds match up to a constant factor. The results are summarized in [2].

2. Amplify-and-forward network coding: A major theme of our research has been that of Amplify-and-Forward network coding. We consider a general class of wireless relay networks with a single source-destination pair. Intermediate nodes in the network employ an amplify-and-forward scheme to relay their input signals. In this case the overall input-output channel from the source via the relays to the destination

effectively behaves as an *intersymbol interference channel with colored noise*. Unlike previous work we formulate the problem of the maximum achievable rate in this setting as an optimization problem with no assumption on the network size, topology, and signal-to-noise ratio. Previous work only considered scenarios wherein relays use all their power to amplify their received signals. We demonstrate that this may not always maximize the achievable rate in amplify-and-forward relay networks. The proposed formulation allows us to not only recover known results on the performance of the amplify-and-forward schemes for some simple relay networks but also characterize the performance of such schemes in more complex relay networks which cannot be addressed in a straightforward manner with existing approaches. Our related major results appear in [1].

Further using cut-set arguments, we derive upper bounds on the capacity of general wireless relay networks. Through various examples, we show that a large class of amplify-and-forward relay networks can achieve rates within a constant factor of these upper bounds asymptotically in network parameters. These results are summarized in [4], [5], and [6].

3. Arbitrarily Varying Channels for Gaussian Noise: A key to understanding the truly optimal throughput possible in wireless networks in the presence of adversarial jamming, is to understand the maximal throughput possible in single point-to-point links in the presence of adversarial jamming. This falls under the classical topic of "Arbitrarily Varying Channels". We were able to information-theoretically characterize this optimal throughput for an interesting class of problems, corresponding to so-called "oblivious" jammers. This is a more realistic model of jamming than currently considered in the literature – in our model (unlike in many other models commonly studied), the jammer cannot "see into the future". The results in this direction are summarized in [7].

4. Concatenated code design for wireless networks: To computationally efficient achieve throughputs that are "close" to information-theoretically optimal for large classes of communication problems, we designed codes that are able to use the idea of "concatenation" (multi-layer coding), and thereby, by a "divide-and-conquer" strategy, and hence reduce the complexity of implementation to polynomial-time in the block-length. The results obtained are summarized in [3].

3. Publications

[1] S. Agnihotri, S. Jaggi, and M. Chen, "Amplify-and-Forward in Wireless Relay Network," In proceedings of the IEEE Information Theory Workshop (ITW) 2011, Paraty, Brazil, October 2011.

[2] Q. Wang, S. Jaggi, and S.-Y. R. Li, "Binary Error Correcting Network Codes," In proceedings of the IEEE Information Theory Workshop (ITW) 2011, Paraty, Brazil, October 2011.

[3] T. Dikaliotis, H. Yao, A. S. Avestimehr, S. Jaggi, and T. Ho, "Low-Complexity Near-Optimal Codes for Gaussian Relay Networks," In proceedings of the Signal Processing and Communications workshop (SPCOM) Bandalore, India , July 2012.

[4] S. Agnihotri, S. Jaggi, and M. Chen, "Analog Network Coding in General SNR Regime," In proceedings of the IEEE International Symposium on Information Theory (ISIT) 2012, Cambridge, MA, July 2012.

[5] S. Agnihotri, S. Jaggi, and M. Chen, "Analog Network Coding in General SNR Regime: Performance of a Greedy Scheme," In the Proceedings of the International Symposium on Network Coding (Netcod) 2012, Cambridge, MA, June 2012.

[6] S. Agnihotri, S. Jaggi, and M. Chen, "Analog Network Coding in General SNR Regime: Performance of Network Simplification," In the Proceedings of the IEEE Information Theory Workshop (ITW) 2012, Lausanne, Switzerland, September 2012.

[7] F. Hadadpour, M. Jafari Siovashani, M. Bakshi, S. Jaggi, "On AVCs with Quadratic constraints," submitted to the IEEE International Symposium on Information Theory (ISIT) 2013.

Shun Hing Distinguished Lecture Series

To achieve the Institute's mission to promote appreciation of engineering in society through education programs, the Institute has been active in organizing Shun Hing Distinguished Lecture Series. Thirty-two distinguished lectures have been presented by renowned scholars from all cover the world. All these lectures were well received by audience and we will continue to line up and invite outstanding researchers to visit CUHK and to deliver distinguished lectures for the Institute. Hereunder are highlights of some of the Distinguished Lectures between Year 2008 and 2012.

Scaling up MIMO: Opportunities and Challenges with Very Large Arrays

Professor Erik G. Larsson
Head of the Division for Communication Systems
Department of Electrical Engineering (ISY),
Linkoping University (LiU), Sweden

Date: 26 July 2012, Thursday

Abstracts

Very large MIMO (VLM) refers to using antenna arrays with an order of magnitude more elements than in systems being built today, say a hundred antennas or more. VLM is a new research field both in communication theory, propagation, and electronics. The ultimate vision of VLM is that the antenna array would consist of small active antenna units. In cellular systems, VLM offers the prospect of increasing rates and reliability by an order of magnitude and saving an order of magnitude in transmit power. In this talk, I will discuss some of the basic opportunities and challenges associated with the introduction of VLM arrays in cellular communication.

Surgical Navigation and Planning in Computer-Integrated Interventional Medicine: An Information Fusion Perspective

Professor Hongliang Ren
Department of Bioengineering
National University of Singapore
Singapore

Date: 21 June 2012, Thursday

Abstracts

Surgical planning and navigation systems enable surgeons to carry out surgical interventions more accurately and less invasively, by tracking the surgical instruments with respect to the target anatomy. This talk will discuss several relevant aspects of this topic, such as a wireless hybrid navigation system primarily for laparoscopic surgeries, ultrasound based tracking of surgical robots for beating-heart surgeries, and other related studies.

The main topic will focus on a wireless integrated navigation system in laparoscopic surgeries. In order to get the real-time position and orientation measurements of surgical instruments inside the human body, we developed a miniature tracking device, free of the constraints of line-of-sight or entangling sensor wires. The proposed sensor fusion algorithm integrates the information from miniature inertial measurement unit (IMU) and electromagnetic tracking (EMT) devices, based on a quaternion formulation of the system dynamics and sensor models. The experimental results show that the proposed system can meet the tracking requirements, in terms of tracking accuracy, latency and robustness.

EEG Signal Classification — A New Geometric Distance Measure

Professor Kon Max Wong
Canada Research Chair Professor of Signal Processing
Department of Electrical & Computer Engineering
McMaster University, Canada

Date: 31 October 2011, Monday

Abstracts

We study the classification of EEG signals for the determination of the state of sleep of a patient. We employ the power spectral density (PSD) matrices as the feature for the distinction between different classes of EEG signals. This not only allows us to examine the power spectrum contents of each signal as well as the correlation between the multi-channel signals, but also complies with what clinical experts use in their visual judgement of EEG signals. To establish a metric facilitating the classification, we exploit the specific geometric properties, and develop, with the aid of fibre bundle theory, an appropriate metric in the Riemannian manifold described by the PSD matrices. To use this new metric effectively for the EEG signal classification, we further need to find a weighting for the PSD matrices so that the distances of similar features are minimized while those for dissimilar features are maximized. A closed form of this weighting matrix is obtained by solving a convex optimization problem. The effectiveness of using these new metrics is examined by applying them to a collection of recorded EEG signals for sleep pattern classification based on the k-nearest neighbour decision algorithm with excellent outcome.

Play Interference for Communications over MIMO Wireless Networks — To Align or To Cancel?

Dr. Wei Zhang
Senior Lecturer
School of Electrical Engineering & Telecommunications
The University of New South Wales, Sydney, Australia

Date: 20 October 2011, Thursday

Abstracts

There is an increasing research interest in approximate capacity characterization of wireless networks. The degree of freedom (DOF), also known as multiplexing gain or capacity pre-log scaling factor, provides a capacity approximation in the high signal-to-noise ratio (SNR). Recently, much research efforts have been made to characterize the DOF of communication over multiple-input multiple-output (MIMO) interference channels or MIMO X channels. In this talk, a novel interference alignment and cancellation scheme with asymmetric signaling is presented to achieve or approach the upper bound of the DOF of the wireless networks where each transmitter/receiver is equipped with multiple antennas. We first prove that the proposed scheme can obtain the exact upper bound of the DOF for 2-user MIMO X channels with constant channel coefficients for some cases of antenna configurations. Then, we show that the proposed scheme can obtain the DOF of $M/2+N$ when $N<M\leq 2N$ for 3-user MIMO interference channels with constant channel coefficients, where each transmitter and receiver are equipped with M antennas and N antennas, respectively. The achievable DOF is further proved to achieve or approach very close to the upper bound of the 3-user MIMO interference channels.

Robust Statistics for Signal Processing

Professor Abdelhak Zoubir
Professor of Signal Processing and
Head of Signal Processing Group
Technische Universität Darmstadt, Germany

Date: 21 September 2011, Wednesday

Abstracts

Robust statistics continue to gain importance due to an increase of impulsive measurement environments and outliers in practical engineering systems. Classical estimation or detection theory does not apply in such situations and robust statistical methods are sought for. The seminar aims at discussing the most fundamental concepts of robust statistics and at showing their power to solving signal processing problems. First, we highlight the motivation for using robust statistics in real-life situations and how robust statistics can be expected to remedy problems in such practical systems. We then introduce the qualitative and the quantitative definitions of robustness and treat Huber's robust M-estimator (ML-type estimator). We show how robust M-estimators for location and scale are constructed. We then discuss semi-parametric adaptive estimation and give examples of its use. The theoretical treatment is followed by an application of geolocation in Non-Line-of-Sight.

Co-sponsored by:
IEEE Signal Processing Society Hong Kong Chapter

On Legs, Tracks and Wheels — Mobile Robots for Unstructured Environments

Dr. Martin Buehler
Director, Research, iRobot, USA

Date: 6 May 2011, Friday

Abstracts

Our robots must sense the world, move in the world, and forcefully interact with the world. Yet, reliable and cost-effective perception, mobility and manipulation remain challenges to the successful fielding and commercialization of robots in virtually all domains. This presentation will focus on robot mobility and offer insights gained from past work on diverse mobile robot systems. These include R&D-type, bio-inspired legged robots in academia and industry (RHex, BigDog, and others), and commercially successful mobile robots with articulated tracks and wheels at iRobot (Warrior, PackBot, SUGV, Roomba). The presentation concludes with some recent project highlights from the iRobot research group, and a glimpse of new robot prototypes, like the AVA platform.

Embracing Uncertainty and Sparsity for Speech Recognition

Professor Jen-Tzung Chien
Distinguished Professor
Department of Computer Science and Information Engineering
National Cheng Kung University, Taiwan

Date: 8 June 2011, Wednesday

Abstracts

In this talk, I will present our recent studies on machine learning and speech recognition, mainly focus on Bayesian and sparse learning of acoustic and language models. In general, speech recognition involves extensive knowledge of statistical models. Both acoustic and language models are important parts of modern speech recognition systems where the learned models from real-world data are full of complexity, ambiguity and uncertainty. The uncertainty and sparsity coding algorithms are crucial to tackle the model regularization for speech recognition. In acoustic modeling, I will introduce a sparse representation of acoustic features based on a set of state-dependent basis vectors. The Bayesian sensing hidden Markov models can be reliably estimated even from heterogeneous training data. The hybrid dictionary learning and sparse representation is performed. In language modeling, I will address the topic models and present a Dirichlet class language model, which projects the sequence of history words onto a latent class space and maximizes the marginal likelihood over the uncertainties of classes, which are expressed by Dirichlet priors. A Bayesian class-based language model is established.

In this presentation, I will report different evaluations on large vocabulary continuous speech recognition and briefly address a new work of embracing uncertainty and sparsity for blind source separation.

Sampling Theory and Practice: 50 Ways to Sample your Signal

Professor Martin Vetterli
Ecole Polytechnique Federale de Lausanne,
Switzerland and University of California, Berkeley, USA

Date: 22 November 2010, Monday

Abstracts

Sampling is a central topic not just in signal processing and communications, but in all fields where the world is analog, but computation is digital. This includes sensing, simulating, and rendering the real world. The question of sampling is very simple: when is there a one-to-one relationship between a continuous-time function and adequately acquired samples of this function? Sampling has a rich history, dating back to Whittaker, Kotel'nikov, Shannon and others, and is a active area of contemporary research with fascinating new results.

The classic result of sampling is the one on bandlimited functions, where taking measurements at the Nyquist rate (or twice the maximum bandwidth) is sufficient for perfect reconstruction. These results were extended to shift-invariant subspaces and multiscale spaces during the development of wavelets, as well as in the context of splines. All these methods are based on subspace structures, and on linear approximation.

Recently, non-linear methods have appeared. Non-linear approximation in wavelet spaces has been shown to be a powerful approximation and compression method. This points to the idea that functions that are sparse in a basis (but not necessarily on a fixed subspace) can be represented efficiently.

The idea is even more general than sparsity in a basis, as pointed out in the framework of signals with finite rate of innovation. Such signals are non-bandlimited continuous-time signals, but with a parametric representation having a finite number of degrees of freedom per unit of time. This leads to sharp results on sampling and reconstruction of such sparse continuous-time signals, namely that 2K measurements are necessary and sufficient to perfectly reconstruct a K-sparse continuous-time signal. In accordance with the principle of parsimony, we call this sampling at Occam's rate. We indicate an order K3 algorithm for reconstruction, and describe the solution when noise is present, or the model is only approximately true.

Next, we consider the connection to compressed sensing and compressive sampling, a recent approach involving random measurement matrices. This is a discrete time, finite dimensional set up, with strong results on possible recovery by relaxing the l0 into l1 optimization, or using greedy algorithms. These methods have the advantage of unstructured measurement matrices (actually, typically random ones) and therefore a certain universality, at the cost of some redundancy. We compare the two approaches, highlighting differences, similarities, and respective advantages.

Finally, we move to applications of these results, which cover wideband communications, noise removal, distributed sampling, and super-resolution imaging, to name a few. In particular, we describe a recent result on multichannel sampling with unknown shifts, which leads to an efficient super-resolution imaging method.

The Invisible Computing Project

Professor Raj Reddy
Mozah Bint Nasser University Professor
of Computer Science and Robotics
School of Computer Science
Carnegie Mellon University, USA

Date: 8 November 2010, Monday

Abstracts

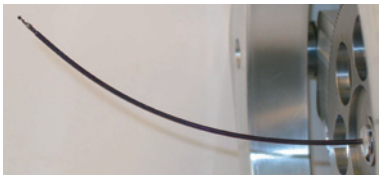
During the late 90s an ambitious project called "Invisible Computing" was launched at CMU to transform the way we use information technology under support from DARPA. It was discontinued for non-technical reasons. It was intended to be a natural successor to Ubiquitous Computing and Pervasive Computing Concepts. It had the characteristics of involving a department wide participation. In this talk I will describe the Vision and the Plan for a Prototype Demonstration of the project.

Jointly organized:
CUHK MoE-Microsoft Key Laboratory of Human-Centric Computing and Interface Technologies

Robotic Surgery Inside the Beating Heart

Professor Pierre E. Dupont
Chief of Pediatric Cardiac Bioengineering
Children's Hospital Boston
Harvard Medical School, USA

Date: 18 October 2010, Monday



Abstracts

Robots have been most successful in applications for which it has been possible to adapt the task to fit the capabilities of the robot. In manufacturing, for example, this has often involved redesigning the product for ease of assembly. In medical applications, it is not possible to redesign the patient, but it is possible to invent new technologies and surgical techniques specifically designed for robotic minimally invasive surgery. One such technology, concentric tube robots, is based on concentrically combining pre-curved elastic tubes. By rotating and extending the tubes with respect to each other, their curvatures interact elastically to position and orient the robot's tip, as well as to control the robot's shape along its length. In this approach, the flexible tubes comprise both the links and the joints of the robot. Since the actuators attach to the tubes at their proximal ends, the robot forms a slender curve comparable in cross section to a catheter, but with a substantially higher tip stiffness. Robot designs are assembled from tube sets based on the surgical procedure and images of the patient's anatomy. This technology requires radically different approaches to solving the standard robotics problems of workspace design, kinematic modeling and real-time control. In this talk, I will discuss our solutions to these challenges illustrated with examples from cardiac surgery where our goal is to convert open-heart surgical procedures to percutaneous beating-heart procedures.

The Golden Age of Speech and Language Science

Professor Mark Liberman
Trustee Professor of Phonetics,
Department of Linguistics
University of Pennsylvania, USA

Date: 4 October 2010, Monday

Abstracts

From the perspective of a linguist, today's vast archives of digital text and speech, along with new analysis techniques and inexpensive computation, look like a wonderful new scientific instrument, a modern equivalent of the 17th-century invention of the telescope and microscope. We can now observe linguistic patterns in space, time, and cultural context, on a scale three to six orders of magnitude greater than in the past, and simultaneously in much greater detail than before. Scientific use of these new instruments remains mainly potential, but the next decade is likely to be a new "golden age" of research. This talk will discuss some of the barriers to be overcome, present some successful examples, and speculate about future directions.

Reverse Engineering of Electronic Devices: An Information Forensic Paradigm

Professor K. J. Ray Liu
Department of Electrical and Computer Engineering
University of Maryland, College Park, USA

Date: 22 September 2010, Wednesday

Abstracts

Information forensics is an emerging new interdisciplinary field concerning about framework, algorithms, and methodology for traitor tracing, content protection, tampering detection, component analysis for intellectual rights protection/infringement, and behavior modeling and analysis for multimedia social networks.

Information forensics is to reconstruct what have happened to the content and to answer who has done what, when and how. To perform forensic analysis, there got to be some traces of evidences. There are invisible traces of evidences left on the content when going through some operations and devices. These "intrinsic fingerprints" can provide powerful forensic evidences regarding the history and provenance of digital content.

In this talk, we will present state-of-the-art advances to identify components inside a electronic device solely from its output by inferring what algorithms/processing are employed and estimating their parameter settings. We will, as an example, discuss a new methodology for forensic analysis of digital camera images based on the observation that color interpolation leaves distinct intrinsic traces on digital images, and these intrinsic fingerprints can then be identified and employed to verify the authenticity of digital data. Using a detailed imaging model and applying component analysis techniques, we can determine which interpolation algorithm is being used, estimate the parameter settings, and thus determine the brand and model of the camera that take this picture.

It can be used for tampering detection as well. Any change or inconsistencies among the estimated in-camera fingerprints, or the presence of new postcamera fingerprints suggests that the image has undergone some kind of processing after the initial capture, such as tampering or steganographic embedding. Building upon such component forensics knowledge, we can extend such a "non-intrusive" forensic methodology to address a number of larger forensic issues in discovering technology infringement and protecting intellectual property rights (infringement forensics), identifying the type and model of acquisition device (acquisition forensics), detecting a variety of content tampering and verifying integrity (tampering forensics), and building universal detector capable of detecting unseen and challenging steganography schemes (steganography forensics), just to name a few.

Walking Assist Robotic System

Professor Kazuhiro Kosuge
Department of Bioengineering and Robotics
Tohoku University, Japan

Date: 6 October 2009, Tuesday

Abstracts

In this presentation, we will consider two types of walking assist systems, a wearable walking assist system and a Passive RT Walker. The original idea of wearable robot assist systems has been proposed in 1960's as a man amplifier, and several prototype systems have been developed for this purpose so far. The wearable robot assist systems are classified into two types; a man amplifier type, which has been developed for augmenting human power, and an assistive device type, which is used to assist the elderly/ disabled to perform daily activities by making up degraded functions. HAL developed by Professor Sankai's group at University of Tsukuba and Wearable Walking Helper developed by our group have been developed as the assistive devices. After having reviewed wearable assist systems developed so far, a control system without using EMG is presented and experimental results illustrate how it works.

Passive RT Walker is a walking assist system of a walker type and is controlled without using electric motors. The system moves by the external force/ moment applied by its user and the motion is controlled by a serve break system. The system is intrinsically safe in that it does not move by itself. By observing its user's state and estimating its user's intention, the dependability of the system is also increased. The passive robotics approach is shown effective as a solution for human-robot interaction without serious safety issues.

From Text to Media: A Unified Approach to Multimedia Pattern Recognition

Professor Chin-Hui Lee
School of Electrical and Computer Engineering
Georgia Institute of Technology, USA

Date: 17 March 2009, Tuesday

Abstracts

With an increasing amount of audio and video materials made available on the web, information extraction from multimedia documents is becoming a key area of growing business and technology interest. Research opportunities range from traditional topics, such as multimedia signal representation, processing, coding, modeling, authentication, and recognition, to emerging subjects, such as language modeling, semantic concept decoding, media data mining, and knowledge discovery. Conventional multimedia processing often focuses on techniques developed for an individual medium. However for multimedia pattern recognition purposes, a number of algorithms are well-positioned and applicable to many cross-media applications.

We present three families of such algorithms. The first, derived from speech and image coding, is unsupervised tokenization of multimedia patterns into a finite set of alphabets through segment or block quantization. Acoustic and visual lexicons can then be constructed. The second, derived from information retrieval, is a vector space representation of multimedia documents via extraction of high-dimensional salient feature vectors using co-occurrences statistics of acoustic and visual words. This can be accomplished through a feature extraction and feature reduction framework, known as latent semantic analysis (LSA), serving as a unified representation of multimedia patterns. This allows us to convert heterogeneous multimedia patterns into uniform text-like documents. Finally we discuss decision-feedback discriminative learning, derived from automatic speech and speaker recognition, for document classification, such as text categorization (TC) or topic identification. Machine learning techniques have been extensively used in the TC community to design discriminative classifiers. We present a recently developed maximal figure-of-merit (MFoM) learning framework for TC. It attempts to optimize parameters for any classifier with any feature representation on any desired performance metric, and was shown to outperform other well-known machining learning algorithms, such as support vector machine (SVM), especially for topics with only very few training documents.

The mathematical formulation of the above three sets of techniques will be described in detail first, followed by their applications to text categorization, automatic image annotation, video story segmentation, audio fingerprinting, and automatic language identification. The three frameworks, all derived from the speech and language processing community, provide a natural linkage to language characterization and concept modeling of multimedia documents and seem to serve as an ideal combination of tools for bridging the gap from conventional, low-level, content-based signal processing to high-level, concept-based processing of multimedia patterns.

Perceptually Motivated Multimedia

Professor Anup Basu

NSERC-iCORE Research Chair in Multimedia
Computing Science Department
University of Alberta, Canada

Date: 8 December 2008, Monday

Abstracts

In this talk we will discuss how biological motivation can help develop better and more robust image processing and computer vision algorithms. More specifically we will outline multi-camera motion estimation, active camera calibration, foveated image/video/3D compression, and the role of spatially varying sensing in 3D perception and depth reconstruction. We will also try to draw similarities between these algorithms and biological processing and understanding of images, and have a discussion with the audience regarding potential new research directions worth investigating.

Innovation: An MIT CSAIL Perspective

Professor Victor Zue

Delta Electronics Professor of Electrical Engineering
Director of Computer Science and Artificial Intelligence Laboratory
Massachusetts Institute of Technology, USA

Date: 31 October 2008, Friday

Abstracts

For more than four decades, the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL) and its predecessors – the Artificial Intelligence Laboratory and the Laboratory for Computer Science, have contributed many technical innovations, ranging from time-sharing and RSA public key encryption to robotics and human-like interfaces. Some of these innovations have spawned successful start-ups or have been acquired by multinationals. In this talk, I would like to offer my personal opinion about the factors contributing to this innovation-rich research environment. I will illustrate my points with examples drawn from past and current research.

Endoluminal Surgery, Endoscopic Microcapsules and Beyond

Professor Paolo Dario
Professor of Biomedical Robotics
Scuola Superiore Sant'Anna, Pisa (Italy)

Date: 24 October 2008, Friday

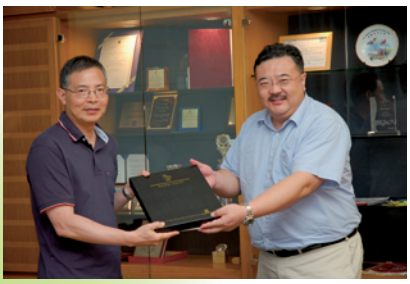
Abstracts

According to the trend of robotic surgery, the current generation of operating robots will be replaced by a second generation designed for minimally invasive and endoluminal access surgery. The need for this kind of surgery is motivated by the progress of diagnostic techniques, which allow to discover pathologies at a very early stage and to treat them when they are limited to a small area of the human body or even to a few cells.

In this scenario, new self-propelled robots for the investigation of hollow organs of the human body, robotic mini-capsules to be swallowed naturally by the patients and teleoperated from outside, programmable re-configurable modular micro-robots able to perform specific bimanual operations inside the human body, are among the most attractive and plausible solutions.

Also robotic solutions for foetal surgery represent a grand challenge for medicine because they have the potential to avoid the development of neonatal pathologies, with a major impact on the quality of life of patients and on the cost reduction for healthcare systems. Finally, nanorobotics represents the ultimate technology for future surgery, allowing to kill specific pathological cells or to treat them with very targeted therapy (up to gene therapy).

In this presentation, the author will describe different biorobotic approaches and solutions to this class of problems, and their vary attractive research, clinical and industrial opportunities.



Direct Design of Orthogonal Filter Banks and Wavelets by Sequential Convex Quadratic Programming

Professor Wu-Sheng Lu

Department of Electrical Engineering
University of Victoria, Canada

Date: 9 September 2008, Tuesday

Abstracts

Two-channel conjugate quadratic (CQ) FIR filter banks are among the most popular building blocks for multirate systems as they offer precise perfect reconstruction property. Most design methods for CQ filters are indirect in that a halfband filter with nonnegativity constraint is designed, followed by a spectrum factorization. This talk describes a direct method that does not require designing the halfband filter and its factorization, and integrates least-square and minimax designs with or without vanishing moment requirement into a single design framework. Examples are supplied to help examine design performance, efficiency, and its ability of getting global solutions.

Sunzi Theorem and Signal Processing

Professor Xiang-Gen Xia

Dept of Electrical and Computer Engineering
University of Delaware, USA

Date: 23 July 2008, Wednesday

Abstracts

Sunzi theorem is also called Chinese remainder theorem (CRT). It is to determine a large integer from its multitple remainders, which is well-known not robust. In this talk, we first talk about its application in frequency estimation in signal processing. We then introduce a generalized CRT that determines multiple integers from multiple remainder sets. Then, we introduce a robust CRT and a robust phase unwrapping. We finally introduce several applications of robust CRT and robust phase unwrapping in SAR imaging of moving targets.

Sponsored Scholarly Events

SHIAE has provided financial sponsorship for Shun Hing Best Student Paper Awards for ISCSLP-2012 and Oriental COCOSDA 2012.

The 15th Oriental COCOSDA Conference (Oriental COCOSDA 2012)

December 9–12, 2012, Macau, China
www.fst.umac.mo/activities/cocosda2012/index.html

Best Student Paper Awards in Oriental COCOSDA 2012

Auliya Sani, Nara Institute of Science and Technology, Japan, and Bandung Institute of Technology, Indonesia

Paper Title: TOWARDS LANGUAGE PRESERVATION PRELIMINARY COLLECTION AND VOWEL ANALYSIS OF INDONESIAN ETHNIC SPEECH DATA

Luying Hou, Institute of Linguistics, Chinese Academy of Social Sciences, Beijing, and Institute of Linguistic Studies, Shanghai International Studies University, Shanghai

Paper Title: PHONETIC MANIFESTATION AND THE INFLUNTIAL FACTORS OF PRONOMINAL ANAPHORIC WORD "TA" IN CHINESE READING TEXTS

Naoya Ukai, Gifu University, Japan

Paper title: CENSREC-2-AV: AN EVALUATION FRAMEWORK FOR BIMODAL SPEECH RECOGNITION IN REAL ENVIRONMENTS

The 8th International Symposium on Chinese Spoken Language Processing (ISCSLP-2012)

December 5–8, 2012, Hong Kong
www.iscslp2012.org/

Best Student Paper Awards in ISCSLP-2012

Mr. Mengxue CAO, Institute of Linguistics, Chinese Academy of Social Sciences, Beijing

Paper Title: ACOUSTIC AND ARTICULATORY ANALYSIS ON JAPANESE VOWELS IN EMOTIONAL SPEECH

Mr. Kuan-Lang HUANG, National Chiao Tung University, Taiwan

Paper Title: TDOA INFORMATION BASED VAD FOR ROBUT SPEECH RECOGNITION IN DIRECTIONAL AND DIFFUSE NOISE FIELD

Mr. Guoli YE, Hong Kong University of Science and Technology, Hong Kong

Paper Title: SPEAKER-ENSEMBLE HIDDEN MARKOV MODELING FOR AUTOMATIC SPEECH RECOGNITION

Mr. Mengxue CAO and Prof PC Ching, Director of SHIAE

Mr. Kuan-Lang HUANG and Prof PC Ching, Director of SHIAE

Annex 1 – List of Completed Reports in BME Track

2010 – 2012	»An inexpensive functional finger prosthesis with rebounded type progressive hinge lock
	»Diffusion Tensor MRI Predictors of Cognitive Impairment in Confluent White Matter Lesion
	»Lanthanide-impregnated molecularly imprinted polymer microspheres as antibody mimics on an optofluidic platform for the detection of disease biomarkers
2009 – 2012	»Signal Processing Strategies on Cochlear Implant Devices for Effective Speech Perception of Tonal Languages
	»Terahertz probe for in vivo imaging
2009 – 2011	»Development of A Robotic Endoscope Holder for Nasal Surgery
2008 – 2010	»Development of highly sensitive and large throughput surface enhanced Raman scattering (SERS) substrates for molecular diagnosis
	»Research on Language and Brain Waves
	»Development of an Efficient Locomotion Mechanism for Wireless Active Capsule Endoscope
2007 – 2009	»Bio-electromagnetic Modeling and Experiment Setup for Medical Electronics RF Safety Assessment
	»Medical Applications of Terahertz Imaging
	»Hybrid Assistive Knee Braces with Smart Actuators
2006 – 2008	»RF Radiation Effect and Efficiency of Wireless Medical Devices on Human Body
	»Photonic biosensor micro-arrays for screening of common cancers
2005 – 2007	»Cochlear Implants
	»Virtual Anatomy and Dexterous Simulators for Minimal Access Cardiothoracic and Neuro-endoscopic Surgeries
	»Systematic Synthesis of Nano-informatics Chips by Nano-Robotics Manipulation

Annex 2 – List of Completed Reports in MMT Track

2010 – 2012	»FADE: Secure Cloud Storage with File Assured Deletion
	»Security and Detection Protocols for P2P-Live Streaming Systems
2009 – 2011	»An Opportunistic Approach to Capacity Enhancement in Wireless Multimedia Networks
	»Computer-Aided Second Language Learning through Speech-based Human-Computer Interaction
2008 – 2010	»Pattern Computation for Compression and Performance Garment
2007 – 2009	»Real-time Transmission of High Definition (HD) 3D Video and HD Audio in Gigabit-LAN
	»High Dynamic Range Image Compression and Display
	»Multimedia Content Distribution over Hybrid Satellite-Terrestrial Communication Networks
2006 – 2008	»Automatic Video Segmentation and Tracking for Real Time Multimedia Services
	»Information Retrieval from Mixed-Language Spoken Documents
	»Wireless Networks and Its Potential for Multimedia Applications
2005 – 2007	»Mobile Wireless Multimedia Communication
	»An Automatic Multi-layer Video Content Classification Framework
	»Automatic Multimedia Fission, Categorization and Fusion for Personalized Visualization in Multimedia Information Retrieval

* Detail report of all completed projects can be found in our Insiitue website : www.shiae.cuhk.edu.hk

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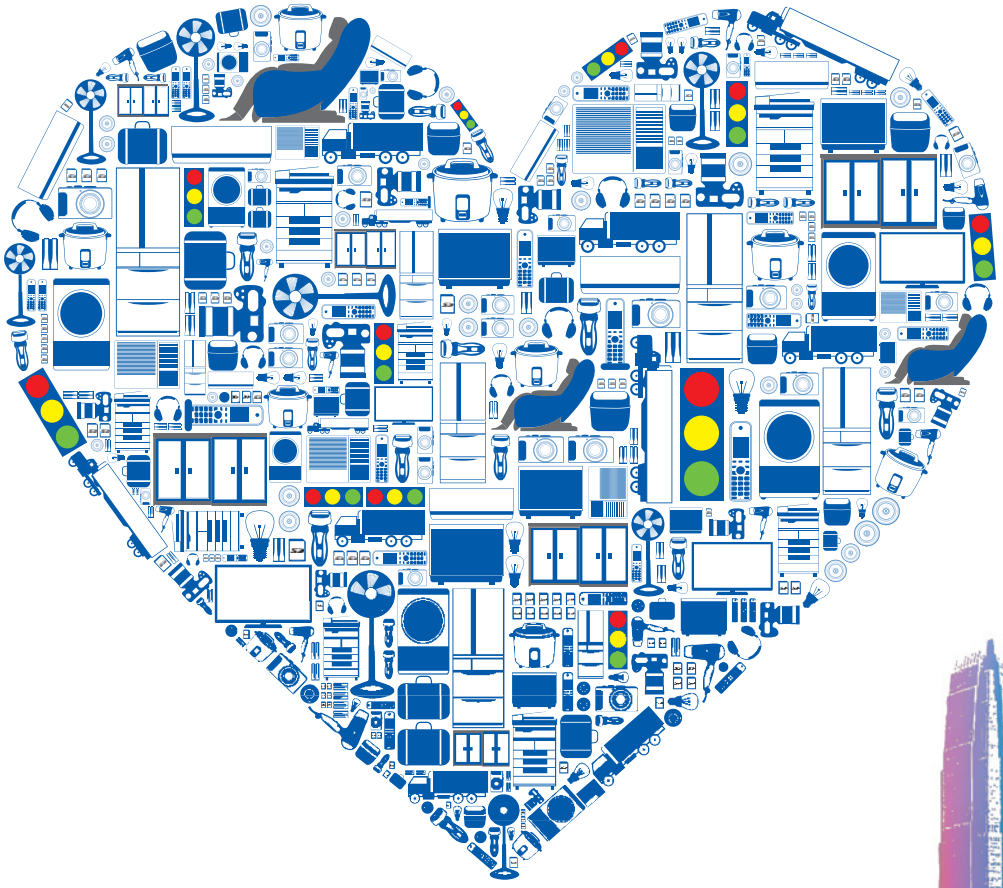

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