2019 IEEE International Conference on Mechatronics and Automation

August 4-7, 2019 Tianjin, China

IEEE IEEE ICMA 2019 Robotics and Automation Society

Welcome Message

Conference Information

Author Index

Program at a Glance

Table of the Contents

IEEE Catalog Number: CFP-19839-CDR
ISBN: 978-1-7281-1697-6

Shuxiang Guo
Kagawa University, Japan
Tel: +81-87-864-2333
Fax: +81-87-864-2369
E-mail: guo@eng.kagawa-u.ac.jp

2019 IEEE International Conference on Mechatronics and Automation

August 4 - 7, 2019
Tianjin, China

Additional copies of Conference Proceedings of 2019 IEEE International Conference on Mechatronics and Automation (ICMA) may be ordered from:

IEEE Service Center
445 Hoes Lane
Piscataway, NJ 08854 U.S.A.

Copyright and Reprint Permission:

IEEE Catalog Number (XPLORE):	CFP19839-ART
ISBN (XPLORE):	978-1-7281-1699-0
Online ISSN (XPLORE):	2152-744X
IEEE Catalog Number (CD-ROM):	CFP19839-CDR
ISBN (CD-ROM):	978-1-7281-1697-6
IEEE Catalog Number (PRINT):	CFP19839-PRT
ISBN (PRINT):	978-1-7281-1698-3

Foreword

On behalf of the IEEE ICMA 2019 Conference Organizing Committee, it is our great pleasure, an honor, and a privilege to welcome you to Tianjin for the 2019 IEEE International Conference on Mechatronics and Automation. This conference reflects the growing interests in the broad research areas of mechatronics, robotics, sensors and automation.

ICMA 2019 marks the 16^{th} edition of the IEEE ICMA annual conference series. We are proud to announce that a high number of **682** papers were submitted from **28** countries and regions, including **658** contributed papers, **24** papers for organized sessions, and **449** papers were accepted for oral or poster presentation at the conference after a rigorous full-paper review process, achieving an acceptance rate of less than **66%**. Presentations at ICMA 2019 are organized in 7 parallel tracks, for a total of **61** sessions, including **1** poster session, taking place during the three conference days. We are fortunate to be able to invite four distinguished speakers to deliver Keynote Speech and plenary talks.

We are very glad that you are joining us at IEEE ICMA 2019 in Tianjin to live this unique experience. The main objective of IEEE ICMA 2019 is to provide a forum for researchers, educators, engineers, and government officials involved in the general areas of mechatronics, robotics, sensors and automation to disseminate their latest research results and exchange views on the future research directions of the related fields. IEEE ICMA 2019 promises to be a great experience for participants from all over the world, with an excellent technical program as well as social activities.

We would like to express our most sincere appreciation and thanks to all of our sponsoring societies and organizations and to all the individuals who have contributed to the organization of this conference. Our special thanks are extended to our colleagues in the Program Committee for their thorough review of all the submitted papers, which is vital to the success of this conference. We must also extend our thanks to our Organizing Committee and our volunteers who have dedicated their time toward ensuring the success of this conference. Last but not least, we thank all the contributors for their support and participation in making this conference a great success. Finally, we wish you a great conference and enjoyable stay in Tianjin, China.

Baofeng Zhang
General Chair

Kazuhiro Kosuge
General Chair

Jian Guo
Program Chair

Shuxiang Guo
Organizing Chair

IEEE ICMA 2019 Conference

International Scientific Advisory Board

Advisory Council Honorary Chairs

T. J. Tarn	Washington University, USA
Toshio Fukuda	BIT and Nagoya University

Advisory Council Chairs

Qingxin Yang	Tianjin University of Tech., China
Tianyou Chai	Northeastern University, China
Hegao Cai	Harbin Institute of Technology, China
Liding Wang	Dalian University of Tech., China
A.A. Goldenberg	University of Toronto, Canada
Kazuhiro Kosuge	Tohoku University, Japan
Paolo Dario	Scuola Superiore Sant'Anna, Italy
Masayoshi Tomizuka	UC Berkeley, USA
Mario A. Rotea	University of Massachusetts, USA
Ju-Jang Lee	KAIST, Korea
Ren C. Luo	National Taiwan University, Taiwan
Yu Yao	Harbin Engineering University, China
Yanrong Li	UESTC, China
Huadong Yu	Changchun University of Science and Technology, China
Zhongmin Su	CUST, China

Organizing Committees

General Chair

Kazuhiro Kosuge — Tohoku University, Japan
Baofeng Zhang — Tianjin University of Technology, China

General Co-Chairs

Qingchun Zheng — Tianjin University of Technology, China
William R. Hamel — University of Tennessee, USA
James K. Mills — University of Toronto, Canada
Darwin G. Caldwell — Italian Institute of Technology, Italy
Makoto Kaneko — Osaka University, Japan
Lixin Dong — Michigan State University, USA
Zhan Yang — Suzhou University, China
Yuxin Zhao — Harbin Engineering Uviversity, China
Yunliang Wang — Tianjin University of Technology, China
Jianda Han — Nankai University, China
Tiejun Li — Hebei University of Technology, China
Shuxin Wang — Tianjin University, China
Yo-Ping Huang — National Taipei University of Technology
Guangtian Shi — Lanzhou Jiaotong University, China

Organizing Committee Chairs

Shuxiang Guo — Kagawa University, Japan
Li Chen — Tianjin University of Technology, China
Fei Chen — Italian Institute of Technology, Italy

Organizing Committee Co-Chairs

Minfang Chen — Tianjin University of Technology, China

Enzeng Dong	Tianjin University of Technology, China
Hideyuki Hirata	Kagawa University, Japan

Tutorial/Workshop Chairs

Guangjun Liu	Ryerson University, Canada
Tao Yue	Shanghai University, China
Weimin Ge	Tianjin University of Technology, China
Wei Wei	Suzhou University, China
Chengzhi Hu	Southern University of Science and Technology, China

Invited/Organized Session Chairs

Yangmin Li	The Hong Kong Polytechnic University, China
Kazuhito Yokoi	AIST, Japan
Chaoyang Shi	Tianjin University, China
Paul Wen	University of Southern Queensland, Australia
Jun Liu	Tianjin University of Technology, China

Awards Committee Co-Chairs

Aiguo Ming	The University of Electro-Communications, Japan
Hong Zhang	University of Alberta, Canada
Shougen Yin	Tianjin University of Technology, China

Publications Chairs

Liwei Shi	Beijing Institute of Technology, China

Publicity Chairs

Xiufen Ye	Harbin Engineering University, China
Bin Liu	Tianjin University of Technology, China

Finance Chair

Libao Cheng	Tianjin University of Technology, China

Hidenori Ishihara	Kagawa University, Japan

Local Arrangement Chairs

Qiang Fu	Tianjin University of Technology, China
Yu Song	Tianjin University of Technology, China

Conference Secretariats

Y. Liu, Z. Wang, S. Gu, L. Zheng	Kagawa University, Japan
Xujie Yang, Zihong Bao, Qi Zhan	Tianjin University of Technology, China

Conference Web System Administrator

Yi Liu	Kagawa University, Japan

Program Committees

Program Chair

Jian Guo	Tianjin University of Technology, China

Program Co-Chairs

Kevin Lynch	Northwestern University, USA
Stefan Byttner	Halmstad University, Sweden
Wan Kyun Chung	POSTEC, Korea
Dongbing Gu	University of Essex, U.K.
Jinjun Shan	York University, Canada
Issam Bahadur	Sultan Qaboos University, Canada
Qing Zhao	University of Alberta, Canada
Dapeng Tian	CIOMP, CAS, China
Hideyuki Sawada	Waseda University, Japan
Koichi Hashimoto	Tohoku University, Japan
Aiqi Qiu	National University of Singapor, Singapore

Yili Fu	Harbin Institute of Technology, China
Yajing Shen	City University of Hong Kong, China
Yizhong Wang	Tianjin University of Science & Technology, China
Limei Song	Tianjin Polytechnic University, China
Shijie Guo	Hebei University of Tech., China
Jingtai Liu	Nankai University, China

International Program Committee

Adachi, Fumiyuki	Addie, Ron	Aiyama, Yasumichi	Althoefer, Kaspar
Ando, Kazuaki	Ang, Wei Tech	Aoyama, Hisayuki	Arai, Fumihito
Arai, Tamio	Arai, Tatsuo	Araki, Kiyomichi	Arzanpour, Siamak
Asada, Minoru	Asama, Hajime	Asano, Toshio	Baeg, Sang Hyeon
Bai, Ou	Ben, Ridha	Ben-Tzvi, Pinhas	Bi, Shusheng
Bi, Zhuming	Bian, Hongyu	Bidaud, Philippe	Bolon, Philippe
Boustany, Nada	Brown, Martin	Byung, Min	Cai, Lilong
Caldwell, Darwin G.	Cao, Maoyong	Ceccarelli, Marco	Chen, Chun-Ta
Chen, Deyun	Chen, Feng	Chen, Guanlong	Chen, I-Ming
Chen, Ken	Chen, Liguo	Chen, Ting	Chen, Weidong
Chen, Weihai	Chen, Wenhua	Chen, Xin	Chen, Xinkai
Chen, Yangquan	Chen, Zhangwei	Cheng, Allen	Cheng, Jianhua
Cheng, Ji-Xin	Cheol, Min	Cheong, Joono	Cho, Young-Jo
Choi, Hyouk Ryeol	Choi, Hyun-Taek	Choi, Junho	Choi, Youngjin
Chou, Wusheng	Chu, Jinkui	Chugo, Daisuke	Chui, Dehua
Chung, Woojin	Cui, Jianwen	Dai, Jiansheng	Dai, Xuefeng
Dailey, Matthew	Damaren, Chris	Dario, Paolo	Davis, Steve
Dechev, Nick	Deco, Gustavo	Deguang, Shang	Demiris, Yiannis
Deng, Yulin	Dillmann, Ruediger	Ding, Jiexiong	Ding, Xilun
Do, Hyun Min	Dodd, Tony	Doh, Nakju	Dohta, Shujiro

Doi, Shunichi	Dong, Hongbin	Dong, Zaili	Du, Pingan
Du, Xiliang	Du, Zhijiang	Duan, Haibin	Dubay, Rickey
Dufosse, Michel	Fan, Jinwei	Fang, Yongchun	Fei, Qin
Feng, Gary	Feng, Weixing	Fiorini, Paolo	Foulloy, Laurent
Fu, Bin	Fu, Jiacai	Fu, Mingyu	Fu, Sheng
Fu, Shuigen	Fu, Yili	FUH, Ying-His	Fujino, Tadashi
Fujisaki, Kiyotaka	Fujisawa, Shoichiro	Fujiwara, Takayuki	Fujiwara, Yoshitaka
Fukuyama, Hidenao	Fung, Wai-Keung	Furusho, Junji	Furuta, Katsuhisa
Furutani, Eiko	Furutani, Katsushi	Furuya, Nobuyuki	Gang, Tong
Gao, baofeng	Gao, Guohua	Gao, Hongtao	Gao, Lin
Gao, Shesheng	Gao, Wei	Gao, Xueshan	Ge, Sam
Ge, Sam Shuzhi	Ge, Yunjian	Gofuku, Akio	Gong, Haixia
Gong, Yadong	Gong, Zhiguo	Graefe, Volker	Gu, Dongbing
Gu, Jason	Gu, Xingzhong	Guan, Yisheng	Guang, Zu Guang
Guglielmelli, Eugenio	Guo, Jian	Guo, Jin	Guo, Maozu
Guo, Mingliang	Guo, Peng	Guo, Shuxiang	Guo, Yi
Habibi, Saeid	Haga, Yoichi	Hamaguchi, Tetsuya	Hamel, William R.
Han, Hongbin	Han, Jiqing	Han, Min	Han, Yujie
Hane, Kazuhiro	Hao, Gang	Harada, Kensuke	Hariri, Alireza
Hasegawa, Osamu	Hasegawa, Tadahiro	Hasegawa, Yasuhisa	Hashimoto, Hiroshi
Hashimoto, Koichi	Hashimoto, Minoru	Hashimoto, Shuji	Hata, Seiji
Hattori, Tetsuo	Hayashi, Jun-ichiro	He, Cunfu	He, Jia
He, Jiping	Hino, Junichi	Hirai, Shigeoki	Hirata, Hideyuki
Hirata, Koichi	Hirata, Yasuhisa	Hirose, Akira	Hong, Keum-Shik
Hong, Seung Ho	Hori, Toshio	Hosoda, Kou	Hou, Mingshan
Hou, Shuping	Hou, Zhenguang	Hu, Chao	Hu, Huosheng
Hu, Jiquan	Hu, Jun	Hu, Jwu-Sheng	Hua, Jun
Huang, Dagui	Huang, Hongzhong	Huang, Ping	Huang, Qiang
Huang, Qingjiu	Huang, Tian	Huang, Yalou	Huasong, Min

Hwan, Chang	Hwan, Dong	IBA, Hitoshi	Ichikawa, Akihiko
Ichiki, Masatoshi	Iguchi, Tetsuhiro	Ikehara, Masaaki	Ikeuchi, Masashi
Ikuta, Koji	Inomo, Hitoshi	Ise, Toshifumi	ishiguro, Hiroshi
Ishihara, Hidenori	Ishihara, Sunao	Ishii, Akira	Ishii, Chiharu
Ishii, Kazuo	Ishii, Koji	Ishikawa, Junzo	Ito, Tomotaka
Iwamura, Yoshiaki	Iwatsuki, Nobuyuki	Izuishi, Kunihiko	Janabi-Shari, Farrokh
Ji, Ping	Ji, Yuehui	Jia, Kebin	Jia, Songmin
Jia, Zhengyuan	Jiang, Pingyu	Jiang, Zhen	Jiao, Shuhong
Jin, Hongzhang	Jin, Rencheng	Jing, Wuxing	Jo, Yongho
Jr., Marcelo H.Ang,	Jung, Kwangmok	Jung, Seul	K.H.Pang, Grantham
Kagami, Shingo	Kagawa, Koji	Kamata, Minoru	Kamiya, Yoshitsugu
Kanamori, Chisato	Kaneko, Shunichi	Kang, Sung Chul	Kang, Taehun
Karaki, Masayuki	Kato, Takahisa	Khajepour, Amir	Kiguchi, Kazuo
Kim, Byeongho	Kim, Doik	Kim, Jinhyun	Kim, Jung
Kim, Keehoon	Kim, Sungshin	Kim, Wheekuk	Kitajima, Hiroyuki
Kitajima, Katsuhiro	Kobayashi, Tetsuo	Kobayashi, Toshihiro	Koh, Kyungchul
Kojima, Masaru	Kok, Tan	Komeda, Takashi	Kometani, Reo
Kong, Xiawen	Konyo, Masashi	Koo, Ja Choon	Koshimizu, Hiroyasu
Kosuge, Kazuhiro	Kotiw, Mike	Kotosaka, Shinya	Kouzani, Abbas
Koyanagi, Kenichi	Koyanagi, Mitsumasa	Kubota, Naoyuki	Kubota, Takashi
Kulkarni，M. S.	Kuno, Yoshinori	Kurazuma, Ryo	Kurisu, Masamitsu
Kuroki, Nobutaka	Kuwakado, Hidenori	Kuwano, Hiroki	Kyriakopou, Kostas J.
Lai, Yongjun	Lan, Hai	Laschi, Cecilia	Laugier, Christian
Lee, Jang Myung	Lee, Jihong	Lee, Songjun	Lee, Yikuen
Li, Bin	Li, Bing	Li, Chunwen	Li, Desheng
Li, Gang	Li, Haisen	Li, Hongsheng	Li, Howard
Li, Jianfeng	Li, Jiangang	Li, Jin	Li, Li
Li, Mantian	Li, Maoxun	Li, Qin	Li, Wenfeng
Li, Xiaoshan	Li, Xiaoyang	Li, Xiukun	Li, Yangmin

Li, Youfu
Li, Yuhua
Li, Yun
Li, Yunhua
Li, Zhang
Li, Zhiyi
Li, Zhiyong
Li, Zhongjian
Lian, Feng-Li
Liang, Guolong
Liang, Yan
Liao, Hongen
Liao, Wei-Hsin
Lin, Chyi-Yeu
Lin, Ming-Tzong
Liu, Bo
Lin, Hsiung-Cheng
Huang, Guo-Shing
Kimura, Kotaro
Tsumaki, Yuichi
Liu, Da
Liu, Dikai
Liu, Fang
Liu, Fanming
Liu, Guangyu
Liu, Haibo
Liu, Honghai
Liu, Hugh
Liu, Jiming
Liu, Jindong
Liu, Jinguo
Liu, Liqiang
Liu, Ming
Liu, Peter X.
Liu, Qing
Liu, Rong
Liu, Xiangdong
Liu, Xiaoping
Liu, Xin-Jun
Liu, Yongguang
Liu, Yugang
Liu, Yunhui
Liu, Zhen
Long, Guilu
Lottin, Jacques
Lou, Yunjiang
Loureiro, Rui
Low, Kin-Huat
Lu, BaoLiang
Lu, Shengfu
Lu, Tien-Fu
M.Chen, Ben
M.Gupta, Madan
Ma, Chunguang
Ma, Shugen
Ma, Xu
Ma, Xudong
Mae, Yasushi
Magnenat-Thalm, Nadia
Mao, Jianqin
Maruyama, Hisataka
Masaki, Yamakita
Masek, Vlastimil
Mashatan, Vahid
Mashec, Vlasitimi
Masuda, Tadashi
Matsuhisa, Hiroshi
Matsunaga, Saburo
Matsuno, Fumitoshi
Matsuno, Takayuki
Matsushige, Kazumi
Maxwell, Andrew
Melchiorri, Claudio
Meng, Max Q.-H.
Meng, Yan
Mills, James K.
Minami, Hirotsugu
Minato, Kotaro
Minemura, Kiyoshi
Ming, Aiguo
Mitsuishi, Mamoru
Miyanaga, Yoshikazu
Miyauchi, Satoru
Mo, Hongwei
Mo, Shuhua
Mochiyama, Hiromi
Morii, Masakatsu
Morikawa, Hiroyuki
Morishige, Koichi
Morishima, Keisuke
Morita, Noboru
Morita, Yoshifumi
Murakami, Toshiyuki
Muscato, Giovanni
Nagata, Fusaomi
Nagatani, Keiji
Nagato, Keisuke
Nakajima, Masahiro
Nakamura, Akio
Nakamura, Hikaru
Nakao, Masayuki
Nakatani, Akihiro
Nakauchi, Yasushi
Nanayakkara, Thrish
Nefti-Meziani, Samia
Nelson, Bradley J.
Ni, Jinping
Ni, Zhonghua
Ning, Hui
Nohmi, Masahiro
Nojima, Toshio
Oana, Hidehiro
Obara, Minoru
Ogose, Shigeaki
Ohara, Kenichi
Ohsawa, Yasuharu

Ohtake, Hiroshi	Oka, Koichi	Okada, Eiji	Oki, Eiji
Okuma, Masaaki	Omichi, Takeo	Oohira, Fumikazu	Osumi, Hisashi
Otake, Mihoko	Otsuka, Akimasa	Ouezdou, Fathi Ben	Ouyang, Puren
P.Miller, David	Pan, Yajun	Pang, Muye	Park, Jong Hyeon
Park, Jooyoung	Park, Sangdok	Payande, Sharam	Perez, Ruben
Pobil, Angel P. del	Prassler, Erwin	Qi, Guangyun	Qi, Hairong
Qi, Naiming	Qiao, Gang	Qiao, Hong	Qiu, Anqi
Qiu, Hua	Radermacher, Klaus	Rao, Wenbi	Ren, Carolyn
Ren, Wei	Ren, Xiangshi	Rhim, Sungsoo	Roh, Segon
Rong, Weibin	Ru, Changhai	Ryeol, Dong	Ryu, Jee-Hwan
Sabatier, Jocelyn	Sabti, Ali	Saito, Takashi	Sakaguchi, Masamichi
Sakai, Shuichi	Sakka, Sophie	Sakurai, Yoshio	Salman, Shaaban Ali
Sampei, Seiichi	Sandini, Giulio	Sawada, Hideyuki	Sekiyama, Kousuke
Semini, Claudio	Shan, Jinjun	Shao, Keyong	Shao, Xinjian
Shen, Yantao	Shen, Yueshi	Sheng, Jie	Sheng, Weihua
Shi, Guangfan	Shi, Haizhang	Shi, Jichuan	Shi, Liwei
Shi, Zhen	Shibata, Takanori	Shimojo, Makoto	Shimotsu, Masateru
Shoham, Moshe	Shriaki, Wataru	Singh, Akash	Soar, Jeffrey
Son, Jaebum	Song, Jae-Bok	Song, Kai-Tai	Song, Quanjun
Song, Zhibin	Stasse, Olivier	Stein, Cathryne	Su, Chanmin Q.
Su, Chun-yi	Su, Liying	Sugar, Tom	Sugita, Naohiko
Suh, Il Hong	Sun, Baoyuan	Sun, Daqian	Sun, Dong
Sun, jinwei	Sun, Kangning	Sun, Xiaojun	Sun, Yong
Sun, Yu	Sun, Zhaowei	Suzuki, Keisuke	Suzuki, Minoru
Suzuki, Takahiro	Suzuki, Yuji	Tadakuma, Kenjiro	Takahashi, Ryoichi
Takahashi, Satoru	Takahashi, Satoshi	Takahashi, Tatsuro	Takaiwa, Masahiro
Takamasu, Kiyoshi	Takasaki, Masaya	Takeda, Takashi	Takeda, Yukio
Takesue, Naoyuki	Takubo, Tomohito	Tan, Jeffrey	Tan, Jindong
Tan, Lihai	Tan, Min	Tan, Zhenfan	Tanaka, Mami

Tanaka, Takayuki	Tang, Mo	Tang, Yike	Tanikawa, Tamio
Tanji, Yuichi	Tao, Nongjian	Tarumi, Hiroyuki	Terada, Hidetsugu
Tian, Yantao	Tomita, Naohide	Tonet, Oliver	Torii, Akihio
Touge, Tetsuo	Tsagarakis, Nikos	Tsai, Ching-Chih	Tsuji, Toshio
Tsukada, Toshihiko	Tsukamoto, Hiroshi	Tsunoda, Okitoshi	Tung, Steve
Ueno, Satoshi	Vachkov, Gancho	Vachkov, Gancho	Vai, Ming-I
Vanderborght, Bram	Vernon, Brent	Vlacic, Ljubo	Voos, Holger
Wada, Masayoshi	Wada, Osami	Wada, Takahiro	Wan, Feng
Wan, Xinhua	Wang, Baikun	Wang, Cheng	Wang, DongMei
Wang, Gang	Wang, Guoli	Wang, Hua	Wang, Joseph
Wang, Keqi	Wang, Lizhen	Wang, Ludan	Wang, Michael Yu
Wang, Peishan	Wang, Pu	Wang, Shuchen	Wang, Shuxing
Wang, Tongyu	Wang, Wen	Wang, Xianghong	Wang, Xiaoyun
Wang, Xin	Wang, Xinsong	Wang, Yafeng	Wang, Yuechao
Wang, Yuezong	Wang, Zhidong	Wang, Zhuo	Wang, Zongyi
Wang, Zuobin	Warisawa, Shin-ichi	Watanabe, Keigo	Watanabe, Mutsumi
Wei, Wei	Wen, Bangchun	Wen, Paul	Wong, Pak-Kin
Wu, Changhua	Wu, Gang	Wu, Jinglong	Wu, Lei
Wu, Shijing	Wu, Xiaofeng	Wu, Xiaojun	X.Yang, Simon
Xi, Jeff	Xi, Zhihong	Xiang, Zhengrong	Xiao, Jizhong
Xiao, Lan	Xiao, Nan	Xie, Lihua	Xie, Ming
Xie, Shane	Xie, Shaorong	Xin, Ming	Xiong, Caihua
Xu, Bo	Xu, Chunquan	Xu, De	Xu, Dingjie
Xu, Fen	Xu, Honghai	Xu, Jianan	Xu, Lixin
Xu, Mengguo	Xu, Qingsong	Xu, Shijie	Xu, Yaoqun
Xue, AnKe	Xue, Dingyu	Yakou, Takao	Yamada, Takayoshi
Yamaguchi, Tomomi	Yamamoto, Manabu	Yamamoto, Motoji	Yamamoto, Yoshio
Yamashita, Atsushi	Yamaura, Hiroshi	Yan, Shaoze	Yan, Shengyuan
Yanagihara, Mamoru	Yang, Enxia	Yang, Erfu	Yang, Fang

Yang, Guiliin	Yang, Hyun Suck	Yang, Jianwu	Yang, Jing
Yang, Kwangjin	Yang, Qingsheng	Yang, Wu	Yang, Xiukun
Yang, Yong	Yang, Yousheng	Yang, Zhaojun	Yano, Masafumi
Yao, Yiyu	Ye, Cang	Ye, Changlong	Ye, Shujiang
Ye, Xiufen	Yi, Byung-Ju	Yi, Chuanyun	Yi, Jianqiang
Yin, Guofu	Yin, Zhengsheng	Yin, Zhouping	Ying, Lixia
Ying, Xianghua	Yokokohji, Yasuyoshi	Yokota, Sho	Yoshida, Shunichi
You, Bo	Young, Nak	Yu, Dejie	Yu, Huadong
Yu, Jie	Yu, Junzhi	Yu, Qiang	Yu, Shui
Yu, Xiaoyang	Yu, Yong	Yu, Yueqing	Yuan, Jianjun
Yuan, Juntang	Yuan, Libo	Yuan, Xiaobu	Yue, Chunfeng
Yue, Dong	Yue, Yong	Yun, Chao	Yuta, Shinichu
Zeng, Chunnian	Zha, Hongbin	Zhang, Baida	Zhang, Chengjin
Zhang, Dan	Zhang, Dianlun	Zhang, Hong	Zhang, Jianpei
Zhang, Jianwei	Zhang, Jinxiu	Zhang, Lei	Zhang, Lijun
Zhang, Lixun	Zhang, Mingjun	Zhang, Rubo	Zhang, Songyuan
Zhang, Xianmin	Zhang, Xiaolong	Zhang, Xiaoyu	Zhang, Xinming
Zhang, Xuping	Zhang, Yanhua	Zhang, Yi	Zhang, Yimin
Zhang, Yong	Zhang, Yongde	Zhang, Yonggang	Zhang, Youmin
Zhang, Yunong	Zhang, Zhaohui	Zhang, Zhe	Zhao, Cangwen
Zhao, Chunhui	Zhao, Lin	Zhao, Qing	Zhao, Xin
Zhao, Xinhua	Zhao, Yuxin	Zhao, Zhijun	Zheng, Fei
Zheng, Guibin	Zheng, Jinyang	Zheng, Yuanfang	Zhong, Ning
Zhou, Xunyu	Zhu, Chi	Zhu, Chunbo	Zhu, George
Zhu, Jianguo	Zhu, Qidan	Zhu, Xiangyang	Zhu, Xiaorui
Zhu, Xilin	Zhu, Yu	Zu, Jean	Zyada, Zakarya

IEEE ICMA 2019 Conference

Cosponsors

Cosponsored by

IEEE Robotics and Automation Society

Tianjin University of Technology, China

Kagawa University, Japan

Beijing Institute of Technology, China

Technically cosponsored by

National Natural Science Foundation of China

Chinese Mechanical Engineering Society

Chinese Association of Automation

State Key Laboratory of Robotics and System (HIT)

Beijing Institute of Technology

The Institute of Advanced Biomedical Engineering System, BIT

Key Laboratory of Convergence Medical Engineering System and Healthcare Technology, the Ministry of Industry and Information Technology, Beijing Institute of Technology

Kagawa University

Tianjin University of Technology

Tianjin Key Laboratory for Control Theory & Applications in Complicated Systems,

Tianjin Key Laboratory for Advanced Mechatronics System Design and Intelligent Control, Tianjin University of Technology

Tianjin International Joint Research and Development Center, Tianjin University of Technology

Engineering Research Center of Optoelectronic Devices & Commnunication Technology, Ministry of Education, China

Harbin Engineering University

The Robotics Society of Japan

The Japan Society of Mechanical Engineers

Japan Society for Precision Engineering

The Society of Instrument and Control Engineers

University of Electro-Communications

University of Electronic Science and Technology of China

Changchun University of Science and Technology

Hebei University of Technology

Heilongjiang Society of Biomedical Engineering

Changchun Institute of Optics, Fine Mechanics and Physics

Optics and Precision Engineering

General Information

Tianjin

Tianjin is one of China's four municipalities under the direct administration of central government. It is an international port city and the largest seaside city in the North of China, 137 km away from Beijing, the capital of China. Tianjin is a birthplace of modern industry of China: the first wrist watch, bicycle and television in New China were all made here. Since 1980s, Tianjin has turned itself into an important industrial base in North China. Tianjin is also a transportation hub with railway, waterway, highway and airway connecting other major cities in China and outside the country.

The name of Tianjin, which means “Emperor's port”, was adopted in the first year of Yongle Reign in Ming Dynasty. In the second year of Yongle Reign(1404), Tianjin became a walled garrison and began to be known as “Tianjin Wei”. In 1860 Tianjin was opened as a trading port. In the 1930s, it became the largest industrial and commercial city and financial center in the north of China. After the founding of the People's Republic of China in 1949, Tianjin became a municipality directly under the central government. After China adopted the policy of reform and opening up in 1978, Tianjin became one of the first coastal cities that are open to the outside world. Today, the city function according to the central government has been designated as becoming an international harbor city, economic center in north China, and an ecological city.

As one of the first cities open to the outside world, Tianjin has an excellent environment for business and investment. Up till now, among the top 500 world leading enterprises, more than 120 have invested in Tianjin. With the involvement of Binhai New Area in the national development strategy, Tianjin has become an area with the greatest attraction for investors and the highest investment profit rates in China.

Tianjin is a well known city with a long history and abundant resources. Panshan Mountain, the No. 1 Mountain in Capital's East; Dule Temple, one of the oldest wooden structures in China; Ancient Culture Street, full of ancient Chinese culture and Tianjin custom. More surprises are waiting for your exploration.

Attractions

➢ Dule Temple

Dule Temple is a Buddhist temple located in the town of Jixian, in Ji County, under the administration of the city of Tianjin, China. The temple is of historical as well as architectural significance. Its oldest surviving buildings are two timber-frame structures, the front gate and the central hall that houses a colossal clay statue of the goddess Guanyin. Both structures date back to the Liao Dynasty and are among the oldest surviving wooden buildings in China.

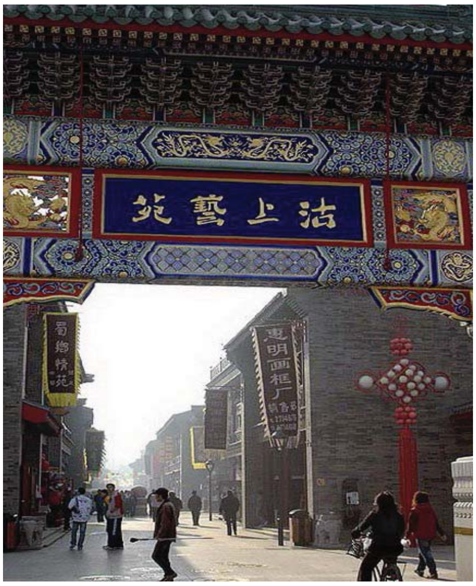
➢ Shi Family Grand Courtyard

Shi Family Grand Courtyardis situated in Yangliuqing Town of Xiqing District, which is the former residence of wealthy merchant Shi Yuanshi – the 4th son of Shi Wancheng, one of the eight great masters in Tianjin. First built in 1875, it covers over 6,000 square meters, including large and small yards and over 200 folk houses, a theater and over 275 rooms that served as apartments and places of business and worship for this powerful family. Shifu Garden, which finished its expansion in October 2003, covers 1,200 square meters, incorporates the elegance of imperial garden and delicacy of south garden. Now the courtyard of Shi family covers about 10,000 square meters, which is called the first mansion in North China. Now it serves as the folk custom museum in Yangliuqing, which has a large collection of folk custom museum in Yanliuqing, which has a large collection of folk art pieces like Yanliuqing New Year pictures, brick sculpture.

Shi's ancestor came from Dong'e County in Shandong Province, engaged in water transport of grain. As the wealth gradually accumulated, the Shi Family moved to Yangliuqing and bought large tracts of land and set up their residence. Shi Yuanshi came from the fourth generation of the family, who was a successful businessman and a good household manager, and the residence was thus enlarged for several times until it acquired the present scale. It is believed to be the first mansion in the west of Tianjin.

Today, the Shi mansion, located in the township of Yangliuqing to the west of central Tianjin, stands as a surprisingly well-preserved monument to China's pre-revolution mercantile spirit. It also serves as an on-location shoot for many of China's popular historical dramas. Many of the rooms feature period furniture, paintings and calligraphy, and the extensive Shifu Garden.

➢ Ancient Cultural Street



Tianjin Ancient Culture Street with 600 years history, standing in the area of key section in upstream of the Haihe River, is located in Nankai district of Tianjin. Covering an area of 224,200 sq meters, it used to be one of earliest water transport docklands in Tianjin where is one of the busiest cities of commerce and trade in history. As a cultural precinct, Tianjin Ancient Culture Street is well known by the local and overseas tourists. The two attractions, Yuan Huang Ge and Tian Hou Temple are two historic cultural relics in the list of city level ones reversed.

Tianjin Ancient Cultural Street rebuilt in 1980's is one of the great successes in the renovation and redevelopment. The whole block is still conserved the existing urban pattern and tissue of traditional Chinese layout. The lanes and houses in the Street are almost preserved in a good condition with Tianjin local feathers. In past time, whenever the day of 23th of March in lunar calendar was coming, a great ceremony would be held here, which it is said that it is the birthday of heaven Mother.

➢ Goubuli

Goubuli, also sometimes translated as Go Believe, is a brand of stuffed baozi from Tianjin, China. Founded in 1858, it is one of China's longest established brands. Each Goubuli bun has eighteen wrinkles. There are many explanations for the name Goubuli. The oft-quoted one relates to a poor village boy nicknamed Gouzhai. At 14, he became an apprentice at a food store. Thereafter, he set up his own shop specialising in selling steamed, stuffed baozi. His supposedly very delicious baozi soon gained immense popularity in a short period of time. As a result, Gouzhai got too occupied with his business to converse with his customers. So, they started to complain, “Gouzhai does not talk to people”.

Weather

Tianjin features a four season, monsoon-influenced climate, typical of East Asia, with cold, windy, very dry winters reflecting the influence of the vast Siberian anticyclone, and hot, humid summers, due to the monsoon.

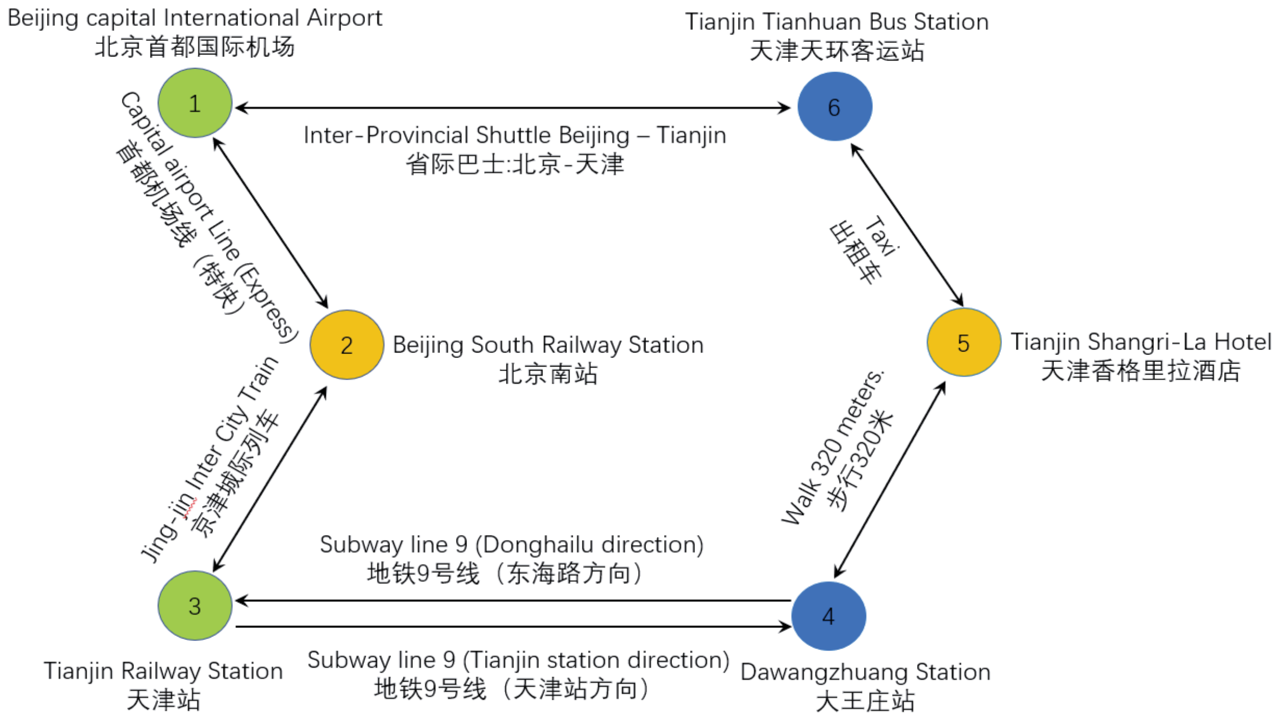
Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
° F	26.8	23.2	43.7	68.9	79.0	86.2	87.8	86.4	79.3	67.5	51.1	39.0
° C	-2.8	-4.9	6.5	20.5	26.1	30.1	31.0	30.2	26.3	19.7	10.6	3.9

Transportation

All the registrants should make their own local transportation in the city. Travel by taxi is the most convenient and faster option for the journey. Tianjin is not only famous for charming natural scenery but also for large numbers of taxis and cheapest taxis cost: RMB 2.00 per km with base price RMB 8.00 ! Please prepare some changes in advance for taxi fee or subway in the staying in Tianjin. We suggest you wait for taxi at the airport designated taxi station. Please ask for a receipt with the taxi.

<u>Transportations from/to Airport</u>

- Transportations from/to Beijing Capital International Airport



Route 1: Traffic information about the Beijing Capital International Airport (北京首都国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店) (1->2->3->4->5)

1st Step: Between Beijing Capital International Airport (北京首都国际机场) and Beijing South Railway Station (北京南站), you can take Capital Airport Line (Express) (机场线) or Taxi.

PS 1: If you take Capital Airport Line (Express) (机场线) for Beijing South Railway Station (北京南站), You will need to change Line2 (2 号线) at Dongzhi Men (东直门) and then change Line 4 (4 号线) at Xizhi Men (西直门). From Beijing South Railway Station(北京南站) to Beijing Capital International Airport (北京首都国际机场), you can take Line 4 (4 号线) and then change Line 2 (2 号线) at Xizhi Men (西直门), next change Capital Airport Line (机场线) at Dongzhi Men (东直门). The one-way fee is about 30 RMB.

PS 2: If you take taxi, the distance is about 37.2 km and you need to pay about 120 RMB.

2nd Step: Between Beijing South Railway Station (北京南站) and Tianjin Railway Station (天津站), please take Jing-jin Inter city Train (京津城际列车).

PS: The train runs from AM 6:13 to PM 10:56 with interval of 20 minutes every day and the one-way time is about 33 minutes. The fee is about 66 RMB.

3rd Step: Between Tianjin Railway Station (天津站) and Tianjin Shangri-La Hotel (天津香格里拉酒店), you can take Subway line 9 or Taxi.

PS 1: If you take taxi, the distance is about 2.4 km and you need to pay about 9 RMB.

PS 2: If you take Subway line 9, from/to Tianjin Railway Station (天津站) to/from Dawangzhuang Ave station (大王庄站), you need to pay about 2 RMB and you can take the Exit C. You can walk to Tianjin Shangri-La Hotel (天津香格里拉酒店) with 320m.

Route 2: Traffic information about the Beijing Capital International Airport (北京首都国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店) (1->5->5)

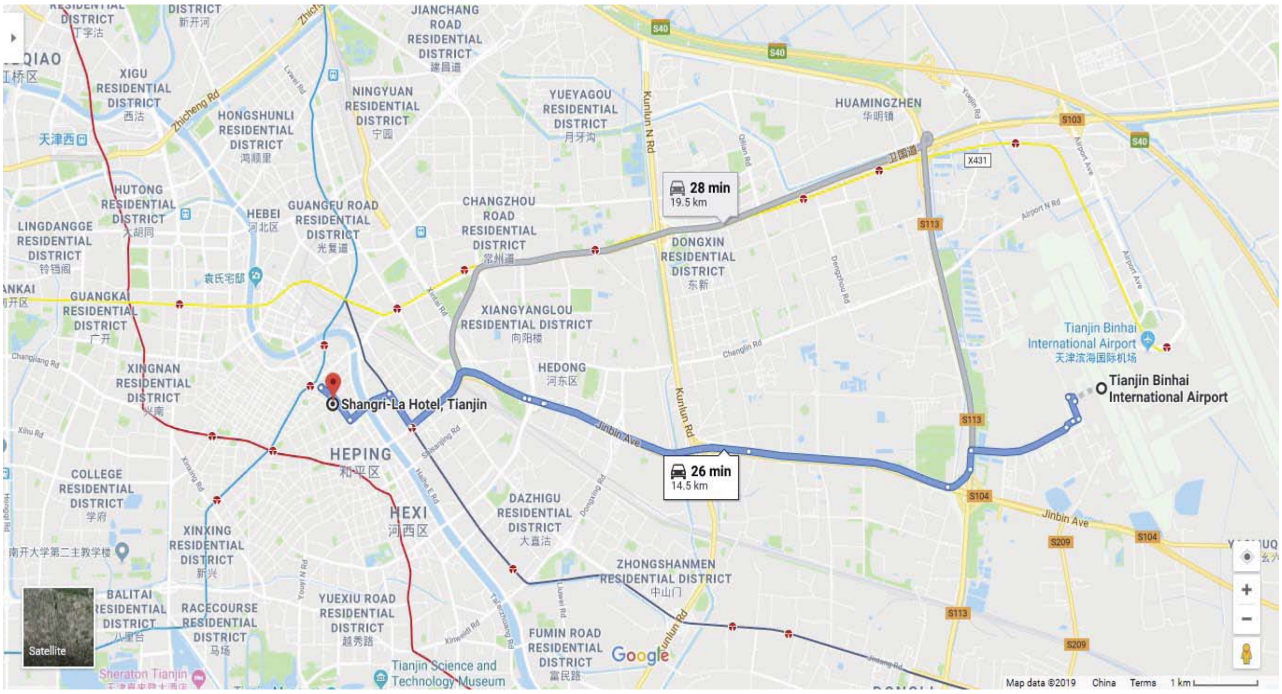
1st Step: From/to Beijing Capital International Airport (北京首都国际机场), you can take Inter-Provincial Shuttle Beijing – Tianjin (省际巴士:北京-天津) to/from Tianjin Tianhuan Bus Station (天津天环客运站) which will take 2 hours and a half and 82 RMB.

PS 1: Beijing departure point: T1/T2: In front of Gate 15 on the 1st Floor of T2; T3: In front of Gate 1 on the 1st Floor, departure time is from 8:00 to 23:00 with about 1 hour interval.

PS 2: Tianjin departure point : Starting from the northeast corner of the crossing of Hongqi Rd (红旗路) and Anshan West Avenue (鞍山西道), Tianjin departure time is from 4:00 to 18:00 with about 1 hour interval.

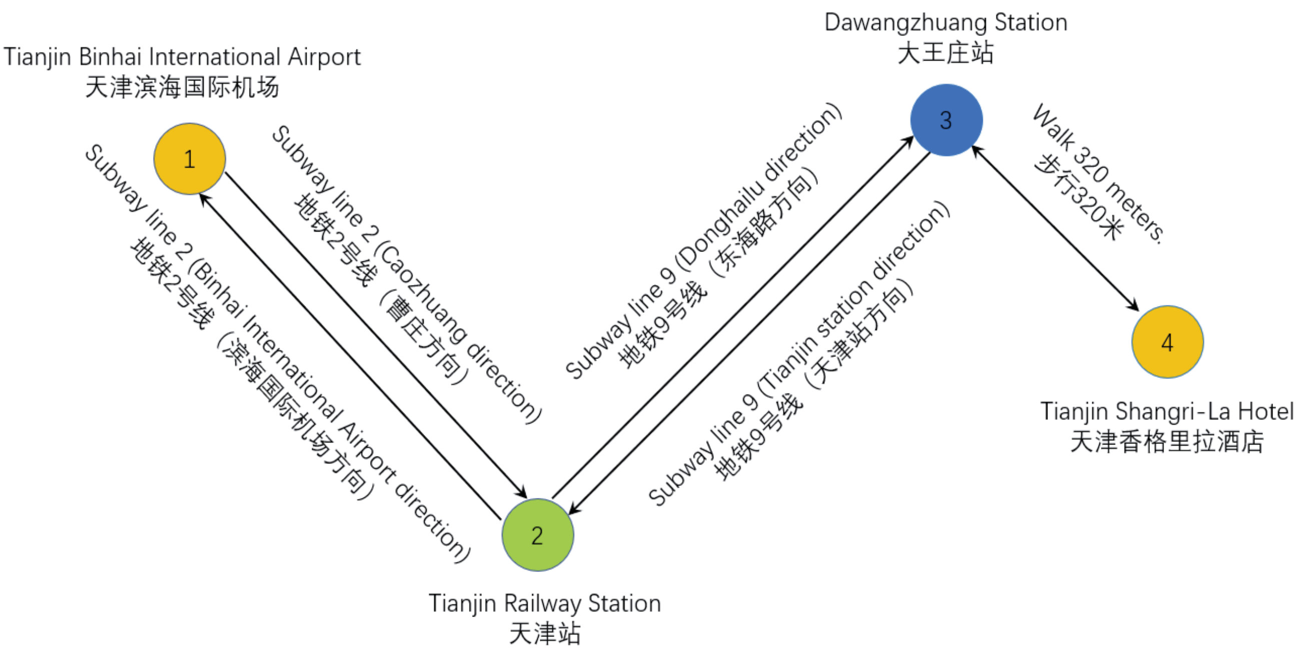
2nd Step: Between Tianjin Tianhuan Bus Station (天津天环客运站) with Tianjin Shangri-La Hotel (天津香格里拉酒店), you can take taxi with about 19 RMB and 30 minutes.

➢ Transportations from/to Tianjin Binhai International Airport by taxi



PS: It will take about 26 minutes. The distance is about 14.5 km and you need to pay about RMB 42 Yuan.

➢ Transportations from/to Tianjin Binhai International Airport by Bus

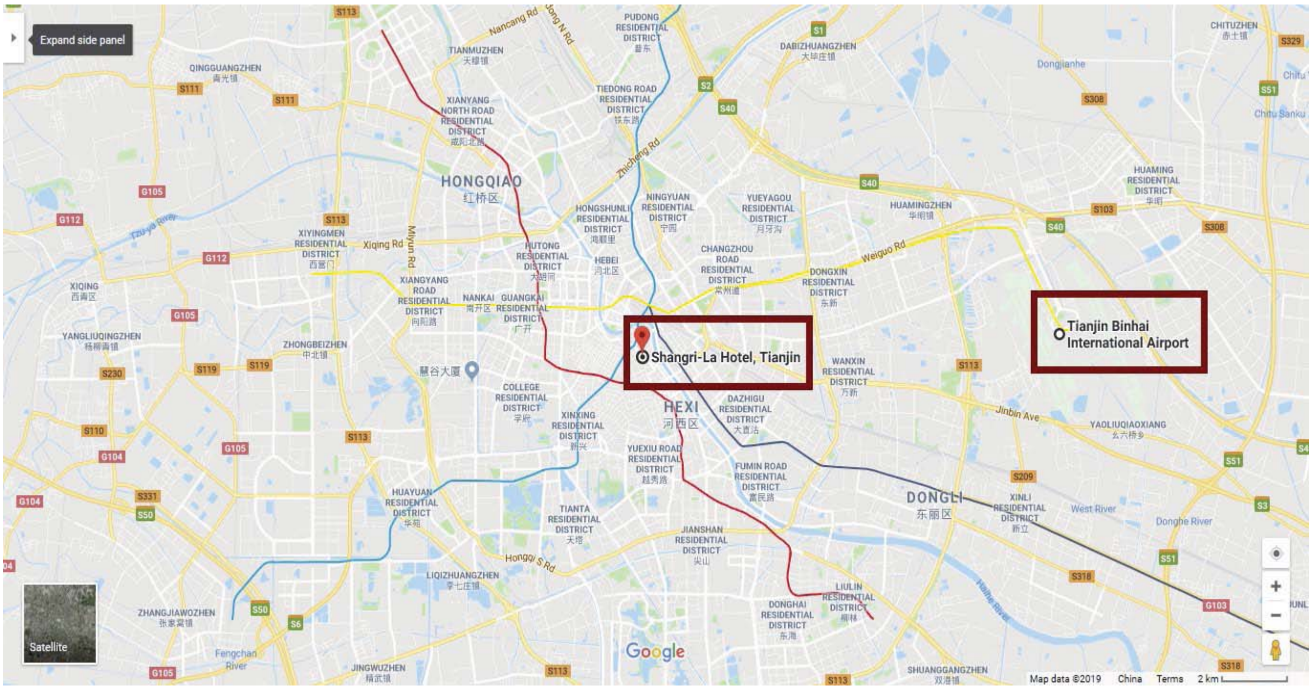


Route: Tianjin Binhai International Airport (天津滨海国际机场) – Tianjin Shangri-La Hotel (天津香格里拉酒店)（1->4）

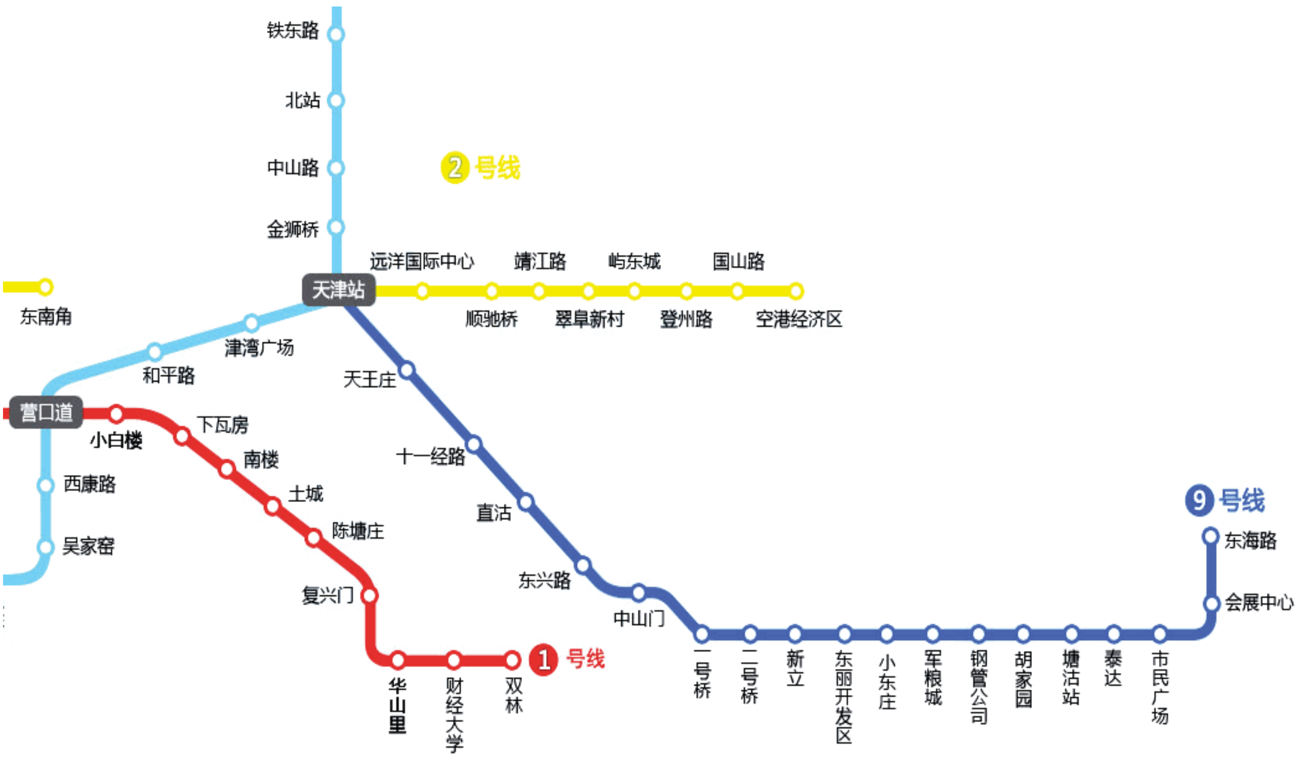
PS : It will take about 43 minutes. The distance is about 17.2 km and you need to pay about RMB 6 Yuan.

Appendix:

➢ The position of Tianjin Shangri-La Hotel



➢ Part of Tianjin Metro



Useful Information

- **Language:** Official language is Mandarin and most people also use their local dialect. The native language in Tianjin is Tianjinese. The standard spoken Chinese is Putonghua. English can be understood by many young people and is used in hotels and big restaurants. In all tourist hotels, staff can speak in English, Japanese and other languages. They can also write down addresses or instructions in Chinese for taxi drivers or others. In addition, roads in major cities are signposted in Pinyin, the official Romanization system of the Chinese characters, which makes it quite easy to get around with the help of a map.

- **Currency:** Renminbi (RMB) is the only currency to be used in China. RMB is also called Chinese Yuan. The unit of Renminbi is yuan and with smaller denominations called jiao. The conversion among the two is : 1 yuan =10 jiao. Paper notes are issued in denominations Aof 1, 5, 10, 20, 50 and 100 yuan. Coins are issued in denominations of 1 yuan; 5 jiao; 1 jiao.

  Money exchanges by cash or travel's cheques can be made at the branches of Bank of China at Tianjin Binhai International Airport, hotels and tourist stores. Please remember to keep the receipt to exchange back to foreign currency when leaving China.

- **Credit Cards:** Visa, Master Card and American Express are the most commonly used in China. Cards can be used in most middle to top-range hotels, department stores, but they cannot be used to finance your transportation costs.

- **Time:** GMT + 8 hours (the whole of China is set to Beijing time)

- **Electricity:** Electricity is 220 Volts, 50 AC; plugs can be three-pronged angled, three-pronged round, two flat pins or two narrow round pins.

- **Water:** Bottled mineral water can easily be bought in all stores and street kiosks for RMB 3. And sometimes hotels provide it free of charge. Furthermore, potable water is only available in a few 4 to 5 star hotels, while water in thermos flasks in rooms is usually non-potable tap water.

- **Measurement:** In Metric system

- **Tipping:** Tipping is not customary outside of the foreign joint-venture hotels and is officially discouraged. But hotel bellboys usually expect RMB 2-5 per bag.

- **Attention:** Smoking is prohibited in public places in Tianjin, such as hospitals, office buildings, theatres, cinemas, museums, planes, and trains.

- **Hotlines:** 110 - Police 119 – Fire 120 – Ambulance

Conference Information

Conference Venue

IEEE ICMA 2019 will be held in the city of Tianjin, at Shangri-La Hotel. Tianjin Shangri-La Hotel located within the fully-integrated Tianjin Kerry Centre, connected to the Riverview Place shopping mall, luxurious residences, and an array of dining and entertainment options. Take the subway to Dawangzhuang Station on line 9 and exit from entrance C or D, which are located in the Riverview Place shopping mall. The hotel is 25-minute drive from Tianjin Binhai International Airport, 5 minutes to Tianjin Railway Station by car and 2 hours' drive from Beijing.

Chinese Address Cards

Tianjin Shangri-La Hotel

天津香格里拉酒店

地址：中国天津市河东区海河东路 328 号
Tel： 86-22-8418-8888

Conference Registration

A conference registration desk will be set up and opened at the FUNCTION ROOM of 1st Floor of Tianjin Shangri-La Hotel from August 4 (13:30) to August 7 (11:00) as followings.

August 4, 2019 13:30~18:30 (near the escalator of 1st Floor)
August 5, 2019 07:30~12:00 (near the escalator of 1st Floor)
August 5, 2019 12:00~18:30 (near Room 6 of 1st Floor)
August 6, 2019 08:00~18:00 (near Room 6 of 1st Floor)
August 7, 2019 08:00~11:00 (near Room 6 of 1st Floor)

Internet Access

Free internet access will be provided during the conference period, to the IEEE ICMA 2019 participants at the Conference Room on 1st floor and 2nd floor of Tianjin Shangri-La Hotel **(天津香格里拉酒店)**. Broadband internet access services are also provided at the conference hotel for a fee. For the fee information, please contact the hotel you are staying directly.

Social Events

The social events organized by the IEEE ICMA 2019 include the conference reception, the awards banquet, the conference registration, the farewell party, etc.

Conference Reception

The Conference Reception will be held from 17:30 to 18:30 on August 4, 2019 in Conference Room 4 (DIAMOND 2), 1F of Tianjin Shangri-La Hotel **(天津香格里拉酒店).** All the conference participants are welcome to join this event.

Awards Banquet

The Awards Banquet will be held from 18:30 to 21:00 on August 6, 2019 in Conference GRAND BALLROM (BALLROM 2), 2F of Tianjin Shangri-La Hotel **(天津香格里拉酒店).** All the conference participants are welcome to join this event.

Farewell Party

The Farewell Party will be held from 12:00 to 13:00 on August 7, 2019 in Conference Room 4 (DIAMOND 2), 1F of Tianjin Shangri-La Hotel **(天津香格里拉酒店).** All the conference participants are welcome to join this event.

IEEE ICMA 2019 Conference

Plenary Talk 1

CPS Driven Control System

Tianyou Chai, Ph.D.

Director of National Research Center for Metallurgical Automation Technology, Professor

Department of Automatic Control

Northeastern University, P.R. China

Abstract:

China has abundance of mineral resources such as magnesite, hematite and bauxite, which constitute a key component of its economy. The relatively low grade, and the widely varying and complex compositions of the raw extracts, however, pose difficult processing challenges including specialized equipment with excessive energy demands. The energy intensive furnaces together with widely uncertain features of the extracts form hybrid complexities of the system, where the existing modeling, optimization and control methods have met only limited success. Currently, the mineral processing plants generally employ manual control and are known to impose greater demands on the energy, while yielding unreasonable waste and poor operational efficiency. The recently developed Cyber-Physical

System (CPS) provides a new key for us to address these challenges. The idea is to make the control system of energy intensive equipment into a CPS, which will lead to a CPS driven control system.This talk presents the syntheses and implementation of a CPS driven control system for energy-intensive equipment under the framework of CPS. The proposed CPS driven control system consists of four main functions: (I) setpoint control; (II) tracking control; (III) self-optimized tuning; and (IV) remote and mobile monitoring for operating condition. The key in realizing the above functions is the integrated optimal operational control methods to implement setpoint control, tracking control and self-optimized tuning together seamlessly. This talk introduces the integrated optimal operational control methods we proposed.

Hardware and software platform of CPS driven control system for energy-intensive equipment is then briefly introduced, which adopts embedded control system, wireless network and industrial cloud. It not only realizes the functions of computer control system using DCS (PLS), optimization computer and computer for abnormal condition identification and self-optimized tuning, but also achieves the functions of mobile and remote monitoring for industrial process.

Then, using fused magnesium furnace as an example, a hybrid simulation system for CPS driven control system for energy-intensive equipment developed by our team is introduced. The results of simulation experiments show the effectiveness of the proposed method that integrates the setpoint control, tracking control, self-optimized tuning and remote and mobile monitoring for operating condition in the framework of CPS.

The industrial application of the proposed CPS driven control system is also discussed. It has been successfully applied to the largest magnesia production enterprise in China, resulting in great returns. Finally, future research on the CPS driven control system is outlined.

Tianyou Chai received the Ph.D. degree in control theory and engineering in 1985 from Northeastern University, Shenyang, China, where he became a Professor in 1988. He is the founder and Director of the Center of Automation, which became a National Engineering and Technology Research Center and a State Key Laboratory. He is a member of Chinese Academy of Engineering, IFAC Fellow and IEEE Fellow.His current research interests include modeling, control, optimization and integrated automation of complex industrial processes.

He has published 200 peer reviewed international journal papers. His paper titled Hybrid intelligent control for optimal operation of shaft furnace roasting process was selected as one of three best papers for the Control Engineering Practice Paper Prize for 2011-2013. He has developed control technologies with applications to various industrial processes. For his contributions, he has won 4 prestigious awards of National Science and Technology Progress and National Technological Innovation, the 2007 Industry Award for Excellence in Transitional Control Research from IEEE Multiple-conference on Systems and Control, and the 2017 Wook Hyun Kwon Education Award from Asian Control Association.

IEEE ICMA 2019 Conference

Plenary Talk 2

Does the progress of robotics pass through soft materials?

Cecilia Laschi, Ph.D.

Professor, Deputy Director

The BioRobotics Institute

Scuola Superiore Sant'Anna, Rector's delegate to research

e-mail: cecilia.laschi@santannapisa.it

https://www.santannapisa.it/en/node/3934

Abstract:

Though a young discipline, robotics progressed rapidly and pervaded our lives more than we perceive, becoming a tool we cannot do without in manufacturing. Futuristic scenarios have been proposing robots in daily life of citizens and professionals for decades, creating expectations that have not yet been matched. What are the realistic scenarios that robotics technologies enable today? What are the abilities

that robots still miss to match expectations for extensive application and healthier and safer human life? Largely inspired by the observation of the role of soft tissues in living organisms, the use of soft materials for building robots is recognized as one of the current challenges for pushing the boundaries of robotics technologies and building robotic systems for service tasks in natural environments. The study of living organisms sheds light on principles that can be fruitfully adopted to develop additional robot abilities or to facilitate more efficient accomplishment of tasks, because living organisms exploit soft tissues and compliant structures to move effectively in complex natural environments.

Robots have a great potential for becoming part of our lives, for responding to current societal challenges, for contributing to economic growth. New materials and new forms of machine intelligence are key directions for the future robotics progress.

Cecilia Laschi is Full Professor at the BioRobotics Institute of Scuola Superiore Sant'Anna in Pisa, Italy, where she serves as Rector's delegate to Research. She graduated in Computer Science at the University of Pisa in 1993 and received the Ph.D. in Robotics from the University of Genoa in 1998. In 2001-2002 she was JSPS visiting researcher at Waseda University in Tokyo.

Her research interests are in the field of soft robotics, a young research area that she pioneered and contributed to develop at international level, including its applications in marine robotics and in the biomedical field. She has been working in humanoid robotics and neurorobotics, at the merge of neuroscience and robotics.

She is in the Editorial Boards of several international journals. She serves as reviewer for many journals, including Nature and Science, for the European Commission, including the ERC programme, and for many national research agencies.

She is senior member of the IEEE, of the Engineering in Medicine and Biology Society (EMBS), and of the Robotics & Automation Society (RAS), where she served as elected AdCom member and currently is Co-Chair of the TC on Soft Robotics. She founded and served as General Chair for the IEEE-RAS First International Conference on Soft Robotics in Livorno, in April 24-28, 2018.

She is founding member of RoboTech srl, spin-off company of the Scuola Superiore Sant'Anna, in the sector of edutainment robotics.

IEEE ICMA 2019 Conference

Plenary Talk 3

The New Wave in Robot Grasping

Ken Goldberg, Ph.D.

Professor and Director

William S. Floyd Jr. Distinguished Chair in Engineering

Department Chair, Industrial Engineering/Operations Research (IEOR)

Director, AUTOLAB and CITRIS "People and Robots" Initiative Founding Member, Berkeley AI Research (BAIR) Lab Joint Appointments: EECS, Art Practice, School of Information (UC Berkeley) and Radiation Oncology (UC San Francisco Medical School).

University of California, Berkeley

E-mail: goldberg@berkeley.edu http://goldberg.berkeley.edu

Abstract:

Robots are about to become far more dextrous based on a new wave in research that combines classical mechanics, stochastic, and deep learning.

Despite 50 years of research, robots remain remarkably clumsy, limiting their reliability for warehouse order fulfillment, robot-assisted surgery, and home decluttering. The First Wave of grasping research is purely analytical, applying variations of screw theory to exact knowledge of pose, shape, and contact mechanics. The Second Wave is purely empirical: end-to-end hyperparametric function approximation (aka Deep Learning) based on human demonstrations or time-consuming self-exploration. A "New Wave" of research considers hybrid methods that combine analytic models with stochastic sampling and Deep Learning models. I'll present this history with new results from our lab on grasping diverse and previously-unknown objects and discuss exciting future research including cloud and fog robotics.

Ken Goldberg is an artist, inventor, and UC Berkeley Professor focusing on robotics. He was appointed the William S. Floyd Jr Distinguished Chair in Engineering and serves as Chair of the Industrial Engineering and Operations Research Department. He has secondary appointments in EECS, Art Practice, the School of Information, and Radiation Oncology at the UCSF Medical School. Ken is Director of the CITRIS "People and Robots" Initiative and the UC Berkeley AUTOLAB where he and his students pursue research in machine learning for robotics and automation in warehouses, homes, and operating rooms. Ken developed the first provably complete algorithms for part feeding and part fixturing and the first robot on the Internet. Despite agonizingly slow progress, he persists in trying to make robots less clumsy. He has over 250 peer-reviewed publications and 8 U.S. Patents. He co-founded and served as Editor-in-Chief of the IEEE Transactions on Automation Science and Engineering. Ken's artwork has appeared in 70 exhibits including the Whitney Biennial and films he has co-written have been selected for Sundance and nominated for an Emmy Award. Ken was awarded the NSF PECASE (Presidential Faculty Fellowship) from President Bill Clinton in 1995, elected IEEE Fellow in 2005 and selected by the IEEE Robotics and Automation Society for the George Saridis Leadership Award in 2016.

More information can be obtained in http://goldberg.berkeley.edu

IEEE ICMA 2019 Conference

Keynote Speech

Cell Processing Task Automation

James K. Mills, Ph. D.

Professor

Department of Mechanical and Industrial Engineering

University of Toronto

5 King's College Rd. Toronto, Ontario Canada

Email: mills@mie.utoronto.ca

http://www.mie.utoronto.ca/labs/nonlin/mills2.html

Abstract:

Interest has grown rapidly over the last decade in biological research and clinical applications involving manipulation and processing of single cells. In research labs a variety of single cell processes are routinely conducted including removal of cell organelles, transfer of RNA, DNA and proteins into the cell and removal of human embryonic cells formed during cell cleavage, amongst others. Currently, much of this cell processing work is carried out manually by highly skilled technicians. This presentation summarizes some of our recent work directed towards the automation of biological micro-scale tasks using robotic technology. The work presented will address control and automation methods utilized to achieve automation of single cell surgery as well as other cell processing automation methods.

James K. Mills is with Department of Mechanical and Industrial Engineering, University of Toronto. He received the PhD in Mechanical Engineering, specializing in robotic control. His recent research interests include: 3D MEMS robotic assembly, meso-scale machine design, control and automation of micro-scale biological tasks. He has published over 450 papers. He has been an Invited Visiting Professor at the Centre for Artificial Intelligence and Robotics in Bangalore, India, a Visiting Professor at the Hong Kong University of Science and Technology, Chinese University of Hong Kong and the City University, Hong Kong.

IEEE ICMA 2019 Conference Workshop

World Premium Workshops on Robotics

Sunday, August 4, 2019
14:00 - 15:40
Conference Room 1, 1F
Tianjin Shangri-La Hotel, Tianjin, China

Regional Analysis of Distributed Parameter Systems and Their Applications for the Control of Cyber–Physical Systems

Venue: Conference Room 1, 1F
Tianjin Shangri-La Hotel, Tianjin
Date and Time: 14:00 - 15:40, August 4, 2019

Organizers:

Dr. YangQuan Chen, University of California, Merced, USA
Dr. Fudong Ge, China University of Geosciences, Wuhan, PR China

About the workshop:

It is well known that Cyber-physical systems (CPSs) with integrated computational and physical processes can be regarded as a new generation of control systems and can interact with humans through many new modalities. The objective of CPS is to develop new science and engineering methods in which sensor and actuator configurations, and physical designs are compatible, synergistic, and integrated at all scales. Many CPSs are characterized by parameters and variables that depend both on time and location so that distributed parameter systems (DPSs) governed by partial differential equations (PDEs) can be used to adequately represent the cyber-physical process dynamics. Moreover, due to the strong interactions between components in these DPS dynamics, there are cases when the system is not controllable or observable in the whole domain of interest but can be controllable and observable in a subdomain. Thus, regional analysis makes more practical sense. Regional sensing and actuation is getting more and more important in this CPS age with cloud computing and big data movements.

This workshop will prepare the IEEE ICMA 2019 audience with 1) compelling reasons why this research theme is important, 2) what are basic concepts and existing results, and 3) what are rich future research opportunities.

List of Speakers and Schedule

Time	Topics	Speaker List
13:55-14:00	Welcome speech	
14:00-14:30	Regional analysis of DPSs and Their Applications for the control of CPSs – 25 years in review	Dr. YangQuan Chen, University of California, Merced, USA
14:30-15:00	Why we should use regional analysis: From MAS-net project to CPS to CHS	Dr. YangQuan Chen, University of California, Merced, USA
15:00-15:30	Regional analysis of fractional order DPSs and Their Applications for the control of CPSs –(Ge)	Dr. Fudong Ge, China University of Geosciences, Wuhan, PR China
15:30-15:40	Panel Discussion	Moderators: All speakers

IEEE ICMA 2019 Conference Workshop

Regional Analysis of Distributed Parameter Systems and Their Applications for the Control of Cyber–Physical Systems

The Workshop speakers

Dr. YangQuan Chen, Professor

Mechatronics, Embedded Systems and Automation (MESA) LAB,

Dept. of Mechanical Engineering, School of Engineering

University of California, Merced

5200 NorthLakeRoad, Merced, CA95343, USA

Emails:yqchen@ieee.org; ychen53@ucmerced.edu; Phone:(209)228-4672

https://scholar.google.com/citations?user=RDEIRbcAAAAJ&hl=en

YangQuan Chen joined University of California, Merced in summer 2012 with a vision to promote the wide-spread use of low cost scientific data-drones in precision agriculture and environmental monitoring. His unmanned aerial systems (UAS) team at UC Merced has been pursuing research excellence in innovative use of data-drones for crop, water, soil, dust, air, and fire etc. Dr. Chen received Ph.D. from Nanyang Technological University Singapore in 1998. His current areas of research interest include: applied fractional calculus in controls, signal processing and energy informatics; distributed measurement and distributed control of distributed parameter systems using mobile actuator and sensor networks; mechatronics; multi-UAV based cooperative multi-spectral "personal remote sensing" for precision agriculture and environmental monitoring. He is an Associate Editor for IFAC journals of Mechatronics and Control Engineering Practice, Fractional Calculus and Applied Analysis, IET Control Theory and Applications, IEEE Transactions of Control Systems Technology, ISA Transactions and Cogent Engineering (Systems and Control). He also serves as the Topic-Editor-in-Chief in "Field Robotics" for International Journal of Advanced Robotic Systems (IJARS), a Senior Editor for International Journal of Intelligent and Robotic Systems, and an associate editor for Journal of Intelligent Service Robotics. He was an associate editor for ASME Journal of Dynamical Systems, Measurement and Control (2009-2015) and a Founding Associate Editor for

Unmanned Systems (2013-2015). Dr. Chen is a member of ASPRS, AUVSI, AMA, IEEE, ASME, AIAA, and ASEE. He serves as the co-chair for IEEE RAS TC on Aerial Robotics and UAV, IEEE-USA CTAP, and Program Co-chair for ICUAS 2016, Washington, DC, and General Co-Chair for ICUAS 2017, Miami, FL. He can be reached by email: yqchen@ieee.org

Dr. Fudong Ge, Associate Professor

School of Computer Science, China University of Geosciences,
Wuhan 430074, PR China
Email: gefd@cug.edu.cn   Phone : +86 18186449217
https://scholar.google.com/citations?hl=zh-CN&user=4rEo3fYAAAAJ

Fudong Ge earned his Ph.D. in the College of Information Science and Technology of Donghua University, Shanghai, China in 2016. He joined the MESA Lab of the University of California, Merced in October, 2014 as an Exchange Ph.D. student. He is now an associate professor at the School of Computer Science, China University of Geosciences, Wuhan, Hubei Province, China. His research interests include existence, stability/stabilization of solutions for fractional differential equations; continuous time random walks and anomalous diffusion systems; distributed measurement and distributed optimal control problems in general distributed parameter systems or cyber-physical systems in general form. He can be reached by email: gefd@cug.edu.cn

Table of Contents

IEEE ICMA 2019

IEEE 2019 IEEE International Conference on Mechatronics and Automation

Robotics and Automation Society

Certificate of Participation

On behalf of IEEE ICMA 2019 Organizing Committee, we appreciated in participation of

Aryuanto Soetedjo

National Institute of Technology (ITN) Malang Indonesia

Indonesia

August 4~7, 2019

Kazuhiro Kosuge
General Chair of IEEE ICMA 2019
Tohoku University,
Japan

IEEE International Conference on Mechatronics and Automation
IEEE ICMA CONFERENCE

Jian Guo
Program Chair of IEEE ICMA 2019
Tianjin University of Technology,
China

Proceedings of 2019 IEEE
International Conference on Mechatronics and Automation
August 4 - 7, Tianjin, China

Intelligent Multi Agent System for Energy Management in the Classrooms with Grid Connected PV

Aryuanto Soetedjo, Yusuf Ismail Nakhoda and Choirul Saleh

Department of Electrical Engineering
National Institute of Technology (ITN) Malang
Jalan Raya Karanglo KM 2 Malang, Indonesia
aryuanto@gmail.com

***Abstract* - This paper presents an application of the Multi Agent System (MAS) in the Building Energy Management System, more specifically to manage the energy in the classrooms of a university. The grid connected photovoltaic (PV) is used as the electrical generation system to supply the loads in the classrooms. The objective is to minimize the electricity cost while maintaining user comfort. The MAS consists of the PV Agent, the Utility Agent, the Load Agent and the Central Control Agent. In addition, the Course Scheduler Unit is employed to inform the utilization or occupancy of the classrooms. The proposed system provides a new method to manage the energy usage from the PV by changing the temperature set-point of the air conditioner system using the Fuzzy Logic Controller. The simulation results show that the proposed system provides the highest performance index of 0.9902 in the optimization of the electricity cost and temperature comfort compared to the conventional method using a fixed temperature set-point.**

Index Terms – Multi agent, energy management, grid connected PV.

I. Introduction

An Intelligent Multi Agent System (MAS) is widely adopted in the distributed control systems [1]. An intelligent agent (or agent) is an autonomous system that acts in the environment to achieve its goal. An agent receives the information from the environment and takes a decision to response the changes according to the goal. In the MAS, several agents collaborate with each other to meet the global objective.

Nowadays, the development of electrical power system increases rapidly in the framework of smart grid technology. The distributed generation becomes popular due to the high penetration of renewable energy resources. Another aspect in the smart grid that attracts the attention is the energy management system. The MAS is adopted in both applications, such as for the microgrid operations [2,3], the renewable energy generation [4], the energy management in smart homes [5-7] and the buildings [8-13].

The MAS was employed to schedule smart devices in multiple smart homes [5]. The objective is to minimize the cost and peak load. In [6], the MAS was proposed to optimize energy usage in a smart home. The multi agents consist of the Management Agents, the Electrical Supply System Agents, and the Home Appliance Agents. There are three agents in the Management Agents, i.e. the Supply Side Management Agent, which is used to manage the power from the supply systems; the Demand Side Management Agent, which is used to manage the power to the loads; and the Home Energy Management Agent, which is used to manage both Supply Side Management Agent and Demand Side Management Agent. The MAS in [7] used the Fuzzy Logic Controller (FLC) which is embedded in each agent of the home appliance. The system was developed to minimize the electricity cost while maintaining the user comfort level.

A four-layer agent consisted of the Switch Agent, the Central Coordinator Agent, the Local Controller Agent, and the Load Agent was proposed in [8] to manage energy in the commercial building. The Local Controller Agent controls the lighting and temperature of the rooms using the FLC. The Central Coordinator Agent coordinates the Switch Agent, the Local Controller Agent, and the Load Agent.

In [11] the MAS was employed in the Building Energy Management System (BEMS). The building is divided into several zones which are controlled by the agents. The agents consist of the Local Zone Agent, the Zone Agent, the On-site Generation Agent, and the Building Agent. The Local Zone Agent controls the environment at the local zone (room), which is composed of the H-agent (heating system), the V-agent (ventilation system), the C-agent (cooling system), the E-agent (lighting and electrical systems) and the U-agent (occupancy level).

Three agents namely the Generation Agent, the Load Agent, and the Storage Agent were proposed to manage the energy operation in the self-sustainable building [12]. The Generation Agent performs the following tasks: analyze and acquire the historical and weather data, control the electrical output, and power conditioning. The Load Agent optimizes the usage of loads of building by performing several tasks, such as load forecasting, appliance management, metering, and load scheduling. The Storage Agent controls the charging/discharging of the battery storage based on the state of charge (SOC) and the charging/discharging rate.

As discussed previously, the MAS in the BEMS is usually divided into the generation agents (and the storage agents), the load agents and the control agents. The loads discussed previously are the general loads in the common building such as the air conditioner, the lighting, etc. In this paper, we deal with the BEMS in a university building, more specifically the lecture rooms or the classrooms. The building is powered by the grid connected PV system. One unique characteristic of our proposed system is that the occupancy of the classroom is well defined by the course schedule. The main contribution of our paper is in the application of MAS to optimize the energy consumed by the classrooms by maximizing the energy from the PV resources while satisfying the temperature comfort in the classrooms. It is conducted by employing the FLC to set the temperature set-point of the classroom according to the power availability of the PV system and the outdoor temperature.

The rest of paper is organized as follows. Section 2 presents the proposed system. Section 3 discusses the simulation results. The conclusion is covered in Section 4.

II. Proposed System

A. System Overview

The configuration of the electrical system is depicted in Fig. 1, where the arrow indicates the electrical flow. As shown in the figure, the electrical power to the loads in the classrooms is supplied by the PV system and the electric utility.

In this research, to simplify the discussion, only five classrooms are considered. However, the proposed system could be extended to cope with a large number of classrooms accordingly. In each classroom, there are three kinds of loads, i.e. the air conditioner (AC), the LCD projector, and the lamps. The LCD projector and the lamps are controlled by on/off mode according to the class utilization. While the AC is a thermostat controlled, in which the temperature set-point is determined by the MAS as described in the next section.

The configuration of MAS to manage the energy consumption in the classroom is depicted in Fig. 2. The Load Agent (LA) is used to control the loads in a classroom. It sets the temperature set-point for operating the AC and switches on/off the lamps and the LCD projector based on the information from the Central Control Agent (CCA) and the Course Scheduler (CSCH). The CCA sends information about the available power of renewable resources. The Course Scheduler (CSCH) is an information system that manages the utilization of classrooms, i.e. the time schedule of the course.

The PV Agent (PVA) is an agent that is responsible to manage the power from the PV. The PVA sends the information about its power to the CCA and gets the control signal related to its power flow from the CCA. The UA is basically a simple agent to control the connection of the utility to the grid according to the signal control sent by the CCA.

CCA is the main control of the whole system. It manages the operation of the loads, the PV system and the utility. The CCA employs the FLC to generate the signal controls to the respective agents. The main objective is to maximize the power while maintaining the user comfort.

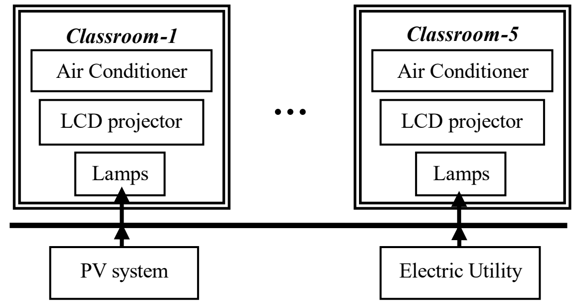


Fig. 1 Configuration of electrical system.

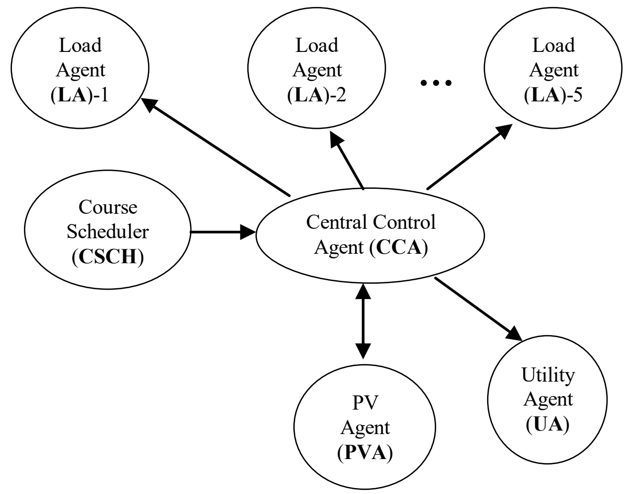


Fig. 2 Configuration of MAS.

B. Multi Agent System

The configuration of the Load Agent (LA) is depicted in Fig. 3. All three loads (AC, lamps, LCD projector) are operated when the classroom is occupied, i.e. there is a course conducted in the classroom. The occupancy information is obtained from the CSCH.

In the current research, the operation of the Lamps and the LCD projector is just switched on/off. While the AC is operated using the thermostat control, i.e. the temperature of the classroom should follow the temperature set-point of AC. By varying the temperature set-point, the energy consumed by the AC could be managed respectively.

As shown in the figure, the agent controls the operation of the loads based on the occupancy of the classroom, the outdoor temperature and the level of renewable energy resources (RES_LEV). The RES_LEV data is sent by the CCA. The RES_LEV is a value that indicates the level of availability of renewable energy resources. This value will be used by the FLC in the LA to set the temperature set-point as discussed in the next section.

The configuration of the PV Agent (PVA) is depicted in Fig. 4. PVA has two main tasks. The first task is to read the weather information and send the predicted PV power to the CCA. The second task is to read the control signal from the CCA and generate a switching signal to the power switch.

The switching signal is used to select the power flow from the PV as follows:

- Grid connection: the PV is connected to the grid
- Disconnected: the PV is disconnected from the system.

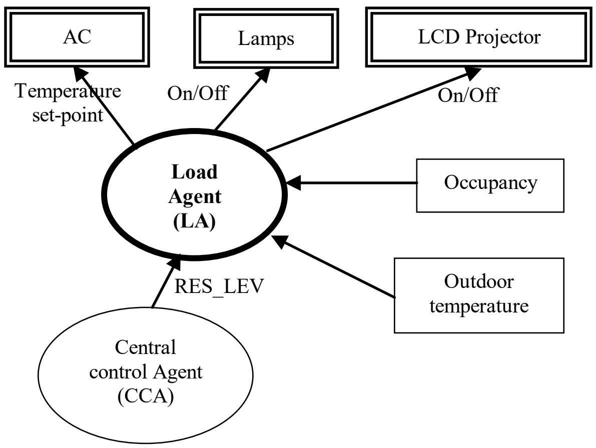


Fig. 3 Configuration of the Load Agent.

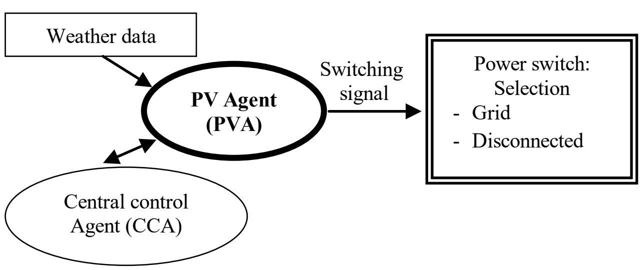


Fig. 4 Configuration of the PV Agent.

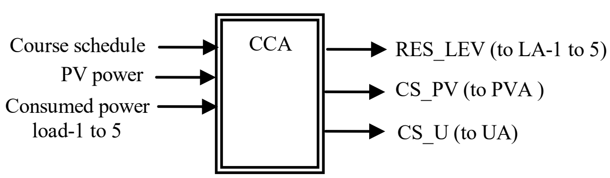


Fig. 5.The input and output of the Central Control Agent.

The CCA generates the control signals to the other agents as depicted in Fig. 5. The control signal to PVA and UA are CS_PV and CS_U, which are used to connect or connect the PV and the utility to the grid.

The control signal to the LA is RES_LEV which is determined by the FLC as described in the following section.

C. FLC in the Central Control Agent

As described previously, the CCA employs the FLC (later on is called as the FLC-CCA) to generate the control signal to the LA, the PVA, and the UA. The architecture of FLC-CCA is depicted in Fig. 6. As shown in the figure, the FLC-CCA has two inputs and one output. The inputs are the available power from the renewable energy resources (RES_PWR=PV power) and the power consumed by the loads (CONS_PWR=Consumed power load-1 to 5). While the output is the level of available power from renewable energy resources (RES_LEV).

The fuzzy membership functions of RES_PWR, CONS_PWR, and RES_LEV are depicted in Fig. 7. Each variable has three linguistic values, i.e. LOW, MED, and HIGH.

Since the objective of MAS is to minimize the electricity cost by maximizing the energy usage from the RES, thus the fuzzy rules are developed in such a way to fulfill that objective. The main idea is to provide information about the availability of RES to the LA. Then the LA uses this information to determine the temperature set-point.

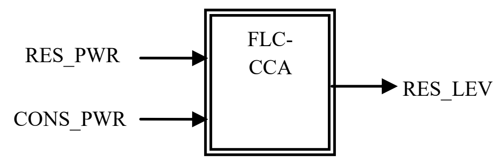


Fig. 6 FLC-CCA architecture.

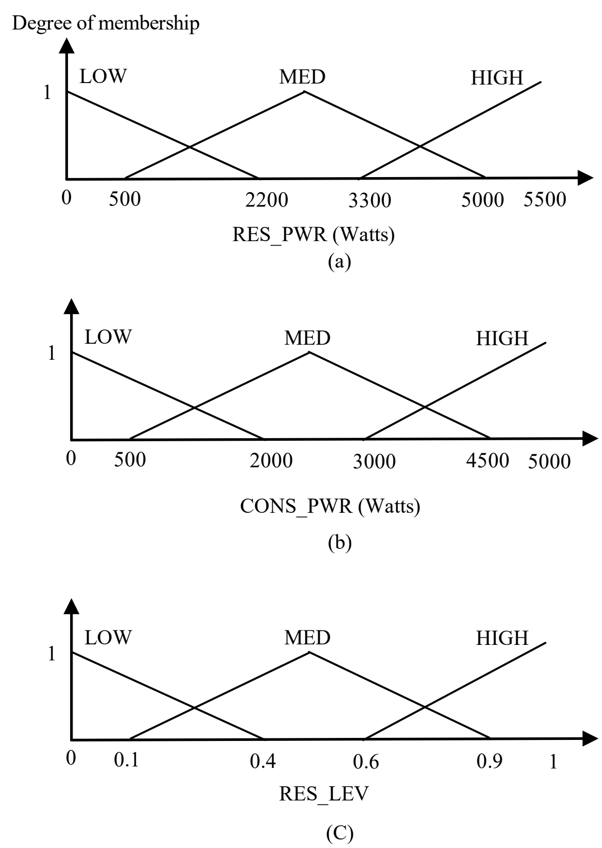


Fig. 7 Membership functions of FLC-CCA: (a) RES_PWR; (b) CONS_PWR; (c) RES_LEV.

TABLE I
FUZZY RULES OF FLC-CCA

CONS_PWR \ RES_PWR	LOW	MED	HIGH
LOW	***MED***	***MED***	***HIGH***
MED	***LOW***	***MED***	***HIGH***
HIGH	***LOW***	***MED***	***MED***

The information about the availability of RES is then called as the RES_LEV and determined based on the RES_PWR and CONS_PWR. The fuzzy rules are listed in Table 1. Several rules from the table could be explained as follows:

- IF RES_PWR is HIGH AND CONS_PWR is LOW THEN RES_LEV is HIGH: There is surplus power from RES, thus the RES_LEV is set to a high level.
- IF RES_PWR is LOW AND CONS_PWR is HIGH THEN RES_LEV is LOW: There is not enough power from RES, thus the RES_LEV is set to a low level.
- IF RES_PWR is MED AND CONS_PWR is MED THEN RES_LEV is MED: The availability of power from RES is medium, thus the RES_LEV is set to medium level.

D. FLC in the Load Agent

The FLC in the LA (later on is called FLC-LA) is used to set the temperature set-point of the AC in the classroom as depicted in Fig. 8. This set-point is determined to satisfy two conditions: a) the temperature set-point is in the range of comfortable level; b) the availability power from RES should be extracted as much as possible.

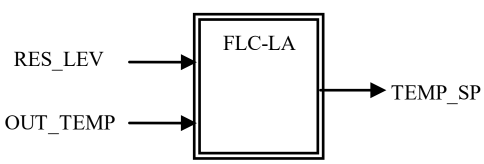


Fig. 8 FLC-LA architecture.

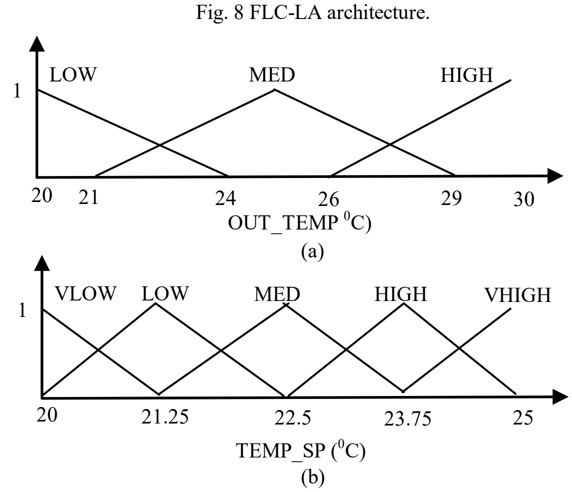


Fig. 9 Membership functions of FLC-LA: (a) OUT_TEMP; (b) TEMP_SP.

TABLE II
FUZZY RULES OF FLC-LA

OUT_TEMP \ RES_LEV	LOW	MED	HIGH
LOW	***VERY HIGH***	***MED***	***VERY LOW***
MED	***HIGH***	***MED***	***LOW***
HIGH	***HIGH***	***MED***	***LOW***

As shown in Fig. 8, the inputs of FLC-LA are the RES_LEV and the outdoor temperature (OUT_TEMP). While the output is the temperature set-point (TEMP_SP). The fuzzy membership function of RES_LEV is the one in the FLC-CCA which is shown in Fig. 7(c). The fuzzy membership functions of OUT_TEMP and TEMP_SP are depicted in Fig. 9. It is noted here that the value of TEMP_SP falls in the range of user comfortable, i.e. from 20 ^{0}C to 25 ^{0}C.

To achieve the goal of minimizing the electricity cost while allowing the temperature comfort, the fuzzy rules are defined as listed in Table 2. The rules are determined based on the idea that by increasing the temperature set-point, the energy consumed by the AC will decrease. Thus when the RES power is low, it is better to increase the temperature set-point and vice versa.

From the fuzzy rules listed in Table 2, several rules are explained as follows:

- IF RES_LEV is LOW AND OUT_TEMP is LOW THEN TEMP_SP is VERY HIGH: There is a small amount power from RES, and the outdoor temperature is low, thus it is a better to set the temperature set-point to very high value for decreasing the energy consumption.
- IF RES_LEV is HIGH AND OUT_TEMP is HIGH THEN TEMP_SP is VERY LOW: There is surplus power from RES, and the outdoor temperature is low, thus it suggests that the temperature set-point could be set to a very low value.

III. SIMULATION RESULTS

To verify our proposed system, we model the system using MATLAB-SIMULINK [14]. The PV generator is simulated using the model developed in [15]. The AC and thermal system of the room are modeled based on the example given in the SIMULINK software [14]. The electrical power rating of the PV and the loads in the classroom are given in Table 3. The data for irradiation, outdoor temperature, course schedule (occupancy of the classroom) are given in Table 4.

The simulation results are depicted in Fig. 10 and Fig. 11. In Fig. 10, the profiles of RES_LEV, outdoor temperature, temperature set-point, classroom temperature of classroom-1 are shown. For convenience, the profiles are shown from 06:00 h to 17:00 h when the classrooms are occupied. From the figure, we can see that at 07:00 h, the classroom-1 is occupied and the PV produces a small power.

Therefore the RES_LEV is low and forces the system to set the temperature set-point to the higher value, i.e. 23 ^{0}C. At 12:00 h, when there is enough power from the PV and the consumed power is also high, then the RES_LEV will have a medium value, i.e. 0.5. It will set the temperature set-point to the medium value, i.e. 22.5 ^{0}C.

Fig. 11 shows the profiles of consumed power of classroom-1 to classroom-5 from 06:00 h to 17:00 h. By observing the top figure, i.e. the consumed power of classroom-1, it is obtained that the consumed power in the morning is lower than the one in the afternoon. This result could be understood by examining Fig. 10 as follows. In the afternoon, the outside temperature is higher than the one in the morning. Since the temperature set-point is about 22.5 ^{0}C, the AC will consume more power in the afternoon to reach the set-point.

TABLE III
POWER RATINGS OF GENERATOR AND LOADS

Generator and Loads	Power rating
PV	3000 W
AC	450 W (per room)
LCD projector	310 W (per room)
Lamps	240 W (per room)

TABLE IV
IRRADIATION, OUTDOOR TEMPERATURE, OCCUPANCY OF CLASSROOM-1 TO 5

Time (hour)	Irradiation (W/m^2)	Outdoor temperature (^{0}C)	Classroom (O=occupied; X=empty)				
			1	2	3	4	5
00:00	0	21	X	X	X	X	X
01:00	0	21	X	X	X	X	X
02:00	0	21	X	X	X	X	X
03:00	0	21	X	X	X	X	X
04:00	0	21	X	X	X	X	X
05:00	0	21	X	X	X	X	X
06:00	0	22	X	X	X	X	O
07:00	200	22	O	X	X	O	O
08:00	300	24	O	O	X	O	O
09:00	500	25	O	O	X	O	O
10:00	700	26	X	O	O	X	O
11:00	900	26	X	O	O	X	O
12:00	900	26	O	O	O	X	X
13:00	800	26	O	X	O	X	O
14:00	600	27	O	X	O	O	O
15:00	400	27	X	X	O	O	O
16:00	300	24	X	X	X	O	X
17:00	0	24	X	X	X	X	X
18:00	0	24	X	X	X	X	X
19:00	0	24	X	X	X	X	X
20:00	0	23	X	X	X	X	X
21:00	0	23	X	X	X	X	X
22:00	0	23	X	X	X	X	X
23:00	0	22	X	X	X	X	X

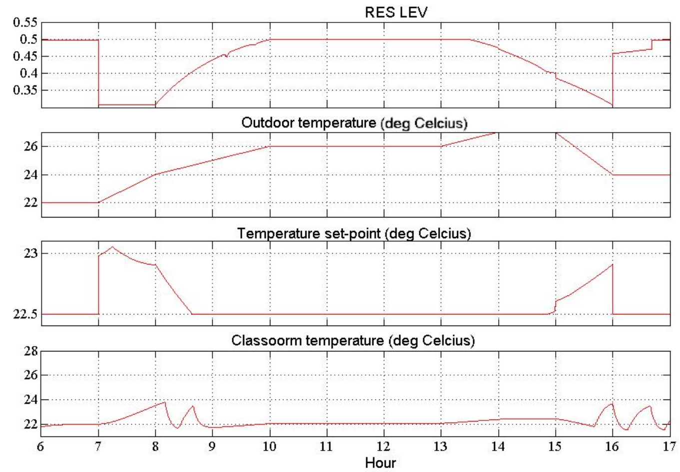


Fig. 10 Profiles of RES_LEV, outdoor temperature, temperature set-point, classroom temperature of classroom-1.

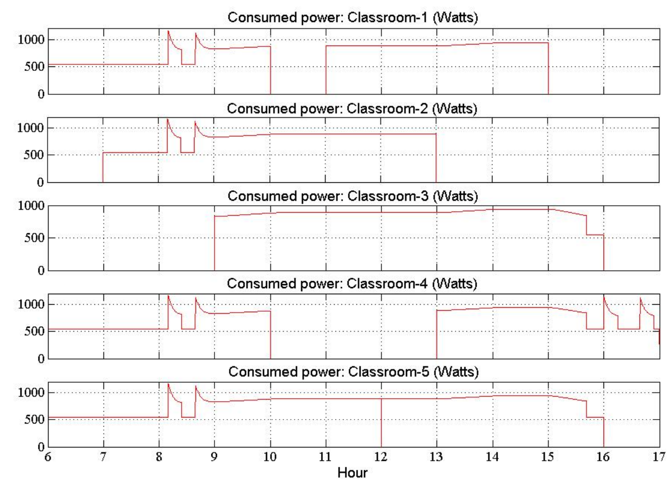


Fig. 11 Profiles of consumed power of classroom-1 to classroom-5.

TABLE V
COMPARISON RESULTS OF PERFORMANCE INDEX

Method		*en_lev*	*cf_lev*	*pi*
Fixed temperature set-point	21 ^{0}C	0.0039	0.8480	0.8519
	22 ^{0}C	0.0498	0.9124	0.9622
	23 ^{0}C	0.1475	0.8276	0.9751
	24 ^{0}C	0.4317	0.3541	0.7858
	25 ^{0}C	0.6358	0.0077	0.6435
Proposed system		0.0989	0.8913	0.9902

To measure the effectiveness of the proposed system in the optimization of the electricity cost and the comfort level, we define the performance index (*pi*) as follows:

$$pi = en\_lev + cf\_lev \quad (1)$$

$$en\_lev = 1 - \sum_{h} (c - p) / \beta) \quad (2)$$

$$cf\_lev = 1 - \sum_{h} \left| st - rt \right| / \gamma) \quad (3)$$

where *en_lev* and *cf_lev* represent the level of electricity cost and the temperature comfort respectively, *c* and *p* are consumed power by the loads and the PV power respectively, *st* and *rt* are the reference temperature and the classroom temperature respectively, β and γ are the constants for normalization, and *h* represents the hour.

In the simulation, we compare our proposed system, i.e. varying the temperature set-point, with the fixed temperature set-point. The comparison results are given in Table 5. It is clearly shown that the proposed method provides the highest value of the performance index (*pi*). It means that our proposed system achieves the highest performance among the other methods (fixed temperature set-point). The table suggests that our proposed system achieves the high index of the temperature level. It conforms with the idea of the proposed algorithm that determining the temperature set-point according to the availability of power from the PV and the outdoor temperature.

In addition, we test our proposed MAS on the embedded system, especially dealing with the execution time, the implementation cost, and the communication interface. The embedded platform is similar to our previous work [16], i.e. using the low cost WeMos module [17]. The main algorithm of each agent is implemented on the WeMos module, which is communicated with other agents via the WiFi communication. From the experiments, the execution time of the FLC is 13 ms and the transfer time between each agent is 332 ms. The results show that our proposed method is suitable for the real-time implementation, in which the update time of building energy management system is usually on hourly basis.

IV. Conclusion

The MAS is proposed to manage the energy in the classrooms by varying the temperature set-point according to the PV power and the outdoor temperature. The FLC is adopted in the agents to find the optimal temperature set-point. The performance index representing the measurement of the level of electricity saving cost and the user comfortable level is developed which is used to compare the proposed system with the fixed temperature set-point. Using the developed performance index, the proposed system achieves the highest value of 0.9902. Further, the possible implementation in the real-time system is verified by a small embedded platform and shows the promising results, in terms of the fast execution time, i.e. less than one minute, and the low cost implementation of the embedded system.

In future, the system will be extended to cope with more complex building. The advanced algorithms will be adopted accordingly. Further the system will be implemented in the hardware prototype.

Acknowledgment

This work is supported by the Research Grant, Excellent Basic Research on Higher Institution scheme (PDUPT) from Directorate General of Higher Education, Ministry of Research and Technology and Higher Education, Republic of Indonesia, 2019.

References

[1] J. Xie and C.-C. Liu, “Multi-agent systems and their applications,“ *Journal of International Council on Electrical Engineering*, vol.7, no. 1, pp. 188-197, July 2017.

[2] H.-M. Kim, Y. Lim and T. Kinoshita,“An Intelligent Multiagent system for Autonomous Microgrid Operation, “ *Energies*, vol 2012, no. 5, pp. 3347-3362, Sep. 2012.

[3] D.O. Elamine, E.H. Nfaoui and J. Boumhidi,“Intelligent multi-agent system for smart microgrid energy management,“ *International Journal of Intelligent Engineering Informatics*, vol. 4, no. 3/4, pp. 245 – 266, Nov. 2016.

[4] R.G. Ramirez and M. Borunda,“An intelligent multi-agent based improved approach for conventional and renewable power generation operation and control, “ *Journal of Renewable and Sustainable Energy*, vol. 9, issue 1, Jan. 2017.

[5] F. Fioretto, W. Yeoh and E. Pontelli, “A Multiagent System Approach to Scheduling Devices in Smart Homes,” in *Proc. of the International Conference on Autonomous Agents and Multiagent Systems* Sao Paulo, 2017, pp. 981–989.

[6] W. Li, T. Logenthiran and W. L. Woo, "Intelligent multi-agent system for smart home energy management," in *Proc. 2015 IEEE Innovative Smart Grid Technologies - Asia* (*ISGT ASIA*), Bangkok, 2015, pp. 1-6.

[7] A. Garrab, A. Bouallegue and R. Bouallegue,”An Agent Based Fuzzy Control for Smart Home Energy Management in Smart Grid Environment,” *International Journal of Renewable Energy Research*, vol. 7, no. 2, pp. 599-612, June 2017.

[8] S. D. Smitha and F. M. Chacko, "Intelligent energy management in smart and sustainable buildings with multi-agent control system," in *Proc. 2013 International Mutli-Conference on Automation, Computing, Communication, Control and Compressed Sensing* (*iMac4s*), Kottayam, 2013, pp. 190-195.

[9] P. Zhao, S. Suryanarayanan and M. G. Simoes, "An Energy Management System for Building Structures Using a Multi-Agent Decision-Making Control Methodology," in *Proc. 2010 IEEE Industry Applications Society Annual Meeting*, Houston, TX, 2010, pp. 1-8.

[10] V. Sutedy, P. Wang, L.H. Koh and F.H. Choo,”Intelligent Eco-Building Management System,” *in Proc. the 5th Annual IEEE International Conference on Cyber Technology in Automation, Control and Intelligent Systems,* Shenyang, 2015, pp. 229-233.

[11] L. A. Hurtado, P. H. Nguyen, W. L. Kling and W. Zeiler, "Building Energy Management Systems — Optimization of comfort and energy use," *2013 48th International Universities' Power Engineering Conference* (*UPEC*), Dublin, 2013, pp. 1-6.

[12] S. Sharma, B. K. Panigrahi and A. Verma, "A Smarter Method for Self Sustainable Buildings: Using Multiagent Systems as an Effective Iterative for Managing Energy Operations," *IEEE Consumer Electronics Magazine*, vol. 7, no. 2, pp. 32-41, March 2018.

[13] S. D. Smitha, J. S. Savier and F. Mary Chacko, "Intelligent control system for efficient energy management in commercial buildings," in *Proc. 2013 Annual International Conference on Emerging Research Areas and 2013 International Conference on Microelectronics, Communications and Renewable Energy*, Kanjirapally, 2013, pp. 1-6.

[14] Thermal Model of a House. [Online]. Available: https://ww2.mathworks.cn /help/simulink/shef/thermal-model-of-a-house.html (Date accessed: 26 May 2019)

[15] PV Array Simulink Block. [Online]. Available: https://ww2.mathworks.cn/ matlabcentral/fileexchange/30326-pv-array-simulink-block (Date accessed: 26 May 2019)

[16] A. Soetedjo, Y.I. Nakhoda and C. Saleh, “Embedded Fuzzy Logic Controller and Wireless Communication for Home Energy Management Systems,” *Electronics*, vol. 7, issue 9, pp. 1-21, Sep. 2018.

[17] An Arduino UNO Compatible WiFi board on ESP8266EX [Online]. Available: https://wiki.wemos.cc/products:d1:d1 (Date accessed: 26 May 2019)