CHEUNG, Howard

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CAREER INTEREST

Modeling and Testing of Heat Pump and Air Conditioning System
Uncertainty Analysis of Models and Experiments
Building Model Applications, Smart Building Technology, Building Energy Audit

EDUCATION

2009 - 2014 **Purdue University, West Lafayette IN, US**
PhD in Mechanical Engineering
Dissertation: Inverse Modeling of Vapor Compression Equipment to Enable Simulation of Fault Impacts
Advisor: Prof. James E. Braun
Final GPA: (3.95/4.00)

2005 - 2009 **The Hong Kong University of Science and Technology (HKUST), Hong Kong**
BEng in Mechanical Engineering and
BBA in General Business Management
Final CGA: (10.98/12.00)
First class honor

SKILLS

Modeling
- Performance Evaluation of Building Audit/ Commissioning Tool
- Building and building equipment modeling for building energy assessment by TRNSYS
- Building model configuration and modification in building simulation software OpenStudio and EnergyPlus, including running multitude of simulations with external cloud computing service (Amazon Web Service)
- Mechanistic and Empirical Mapping of Vapor Compression Systems
- Extrapolation Uncertainty Calculation of HVAC equipment models

Experiment
- Analysis of Building Performance Data from Building Management System (BMS)
- Variable Speed Equipment Testing in Psychrometric Chambers
- Analysis of Field Testing Data from Rooftop Air Conditioning Systems

Teaching
- Preparation of Lecture Notes and Examination Questions
- Lecturing Classes on Thermal Systems

Language
- Native in Cantonese, fluent in English, and fluent in Mandarin

Programming and Software
- Python, OpenStudio (and OpenStudio Server), MATLAB (and with REFPROP), TRNSYS, Git, R, LabView, Ruby, EnergyPlus, SketchUp, LaTeX, Markdown, C++, Fortran, MS Office, SolidWorks

EXPERIENCE

Postdoctoral Fellow, *The Hong Kong Polytechnic University* (2015 - Present)

Development of optimization and diagnosis methods for smart energy management of data centres

Development of optimal energy management strategies and fault diagnosis methods for data centres. Funded by The Hong Kong Polytechnic University

Campus Building Energy Assessment and HVAC Equipment Optimization

Analysis of building data from building management system to explore energy saving potential to retrofit the campus buildings. Funded by The Hong Kong Polytechnic University

Postdoctoral Research Fellow, *Ray W. Herrick Laboratories, Purdue University* (2014 - 2015)

Fault Detection and Diagnostics Algorithms (FDD) of Buildings

Fault models for different HVAC equipment were developed for building simulation program at https://github.com/nrel/openstudio-fault-models for fault detection and diagnostic algorithm development. Funded by National Renewable Energy Laboratory, U.S.A.

Evaluation of Performance of Automatic Building Audit Tool

The performance of an automatic building audit tool was evaluated based on a cost-based analysis and FDD tool evaluation skills. Funded by National Renewable Energy Laboratory, U.S.A.

Graduate Research Assistant, *Ray W. Herrick Laboratories, Purdue University* (2009 - 2014)

Self-learning Power Consumption and Capacity Virtual Sensor for Rooftop Units

Inexpensive smart virtual sensors for power consumption and cooling capacity of rooftop air conditioning units were developed. Funded by Department of Energy, U.S.A.

Inverse Modeling of Faulted Vapor Compression Systems

A modeling methodology was developed to characterize the performance of 11 different vapor compression systems under 5 different types of faults. Funded by National Institute of Standards and Technology, U.S.A.

Mechanistic Modeling of Multi-split Variable-speed Ductless Heat Pump Systems

A cycle model was created to estimate the performance of multi-split variable-speed ductless heat pump systems. Funded by Electric Power Research Institute, U.S.A.

Empirical Modeling and Testing of Variable-speed Ductless Heat Pump Systems

Empirical modeling was conducted on data collected from multiple variable-speed ductless heat pump systems in a laboratory environment. Funded by Ecotope Inc., U.S.A.

Graduate Teaching Assistant, *Purdue University* (2013)

Teaching 68 undergraduate students the basics of thermodynamics in three 1-hour lectures every week, and preparing lecture notes, homeworks, quizzes and examinations

Summer Intern, *The Hong Kong University of Science and Technology* (2008)

Performing computer simulation with Molecular Dynamics Simulation on air damping on microresonators by parallel computing

Summer Intern, *CLP Power Hong Kong Ltd* (2006)

Analyzing the data from structural test of electricity poles and studying the effect of the environmental conditions on the lifespan of the poles

PUBLICATIONS

Journal publications

Cheung, H. and Wang, S., (2018), Impact of Dynamics on The Accuracies of Different Experimental Data Processing Methods for Steady-state Heat Transfer Rate Measurement, *Journal of Thermal Science and Engineering Applications*, 10(2) (Link)

Cheung, H. and Wang, S., (2017), A comparison of the effect of empirical and physical modeling approaches to extrapolation capability of compressor models by uncertainty analysis: A case study with common semi-empirical compressor mass flow rate models, *Journal of Thermal Science and Engineering Applications*, 86, 331-343 (Link)

Cheung, H., Sarfraz, O. and Bach, C. K., (2017), A method to calculate uncertainty of empirical compressor maps with the consideration of extrapolation effect and choice of training data, *Science and Technology for the Built Environment*, (Link)

Cheung, H. and Braun, J. E., (2017), An empirical model for simulating the effects of refrigerant charge faults on air conditioner performance, *Science and Technology for the Built Environment*, 23(5), 776-786, (Link)

Cheung, H. and Braun, J. E., (2016), Minimizing data collection for field calibration of steady-state virtual sensors for HVAC equipment, *International Journal of Refrigeration*, 69, 96-105, (Link)

Cheung, H. and Braun, J. E., (2016), Empirical modeling of the impacts of faults on water-cooled chiller power consumption for use in building simulation programs, *Applied Thermal Engineering*, 99, 756-764, (Link)

Cheung, H. and Braun, J. E., (2016), A general method for calculating the uncertainty of virtual sensors for packaged air conditioners, *International Journal of Refrigeration*, 63, 225-236 (Link)

Cheung, H. and Braun, J. E., (2014), Component-based, gray-box modeling of ductless multi-split heat pump systems, *International Journal of Refrigeration*, 38, 30-45 (Link)

Cheung, H. and Braun, J. E., (2014), Performance Mapping for Variable-speed Ductless Heat Pump Systems in Heating and Defrost Operation,*HVAC&R Research*, 20:5, 545-558 (Link)

Cheung, H. and Braun, J. E., (2014), Performance Comparisons for Variable-Speed Ductless and Single-Speed Ducted Residential Heat Pumps, *International Journal of Refrigeration*, 47, 15-25 (Link)

Cheung, H. and Braun, J. E., (2013), Simulation of Fault Impacts for Vapor Compression Systems by Inverse Modeling Part I: Component Modeling and Validation, *HVAC&R Research*, 19:7, 892-906 (Link)

Cheung, H. and Braun, J. E., (2013), Simulation of Fault Impacts for Vapor Compression Systems by Inverse Modeling Part II: System Modeling and Validation, *HVAC&R Research* , 19:7, 907-921 (Link)

Leung, R., Cheung, H., Gang, H. and Ye, W. (2010), A Monte Carlo Simulation approach for the modeling of free-molecule squeeze-film damping of flexible microresonators. Microfluidics and Nanofluidics, 9:4, 809V818. (Link)

Conference publications

Cheung, H., Wang, S., Zhuang, C., (2017), Development of a simple power consumption model of information technology (IT) equipment for building simulation, *9th International Conference on Applied Energy*, Cardiff, UK, *Accepted*

Cheung, H., Shan, K., Wang, S., (2017), A fault-tolerant control method of balancing valves for condenser fouling in water-cooled chillers, *9th International Conference on Applied Energy*, Cardiff, UK, *Accepted*

PUBLICATIONS (cont.)

Conference publications (cont.)

Bach, C. K. and Cheung, H., (2016), Mapping of Vapor Injected Compressor with Consideration of Extrapolation Uncertainty, *Conference proceedings of ASHRAE Winter Conference 2016*, OR-16-C042 (Link)

Frank, S., Heaney, M., Jin, X., Robertson, J., Cheung, H., Elmore, R. and Henze, G. (2016), Hybrid Model-Based and Data-Driven Fault Detection and Diagnostics for Commercial Buildings, *2016 ACEEE Summer Study on Energy Efficiency in Buildings*, Pacific Grove, California (Link)

Cheung, H. and Bach, C. K., (2015), Prediction of uncertainty of 10-coefficient compressor maps for extreme operating conditions. *IOP Conference Series: Materials Science and Engineering*, 90:1 (Link)

Cheung, H. and Braun, J. E., (2014), Modeling of Fault Impacts for a Multi-split Ductless Heat Pump System. *Proceedings of the 11th IEA Heat Pump Conference 2014*, Montréal, Québec (Link)

Cheung, H. and Braun, J. E., (2014), Virtual Power Consumption and Cooling Capacity Virtual Sensors for Rooftop Units. *Proceedings of the 15th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Yuill, D. P., Cheung, H. and Braun, J. E., (2014), Evaluation of Fault Detection and Diagnostics Tools by Simulation Results of Multiple Vapor Compression Systems. *Proceedings of the 15th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Yuill, D. P., Cheung, H. and Braun, J. E., (2014), Validation of a Fault-Modeling Equipped Vapor Compression System Model Using a Fault Detection and Diagnostics Evaluation Tool. *Proceedings of the 15th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Cheung, H., Nyika, S. and Braun, J. E., (2013), Development and Validation of a Mechanistic Model for Variable-Speed Multi-split Heat Pumps, *ASHRAE Transactions*, 119: B1 (Link)

Cheung, H. and Braun, J. E., (2012), Inverse Modeling to Simulate Fault Impacts for Vapor Compression Equipment Part 1: Component Modeling and Validation, *Proceedings of 14th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Cheung, H. and Braun, J. E., (2012), Inverse Modeling to Simulate Fault Impacts for Vapor Compression Equipment Part 2: System Modeling and Validation, *Proceedings of 14th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Cheung, H. and Braun, J. E., (2012), Performance Mapping for Variable Ductless Heat Pump Systems in Heating, Cooling and Defrost Operation, *Proceedings of 14th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Cheung, H. and Braun, J. E., (2010), Performance Characteristics and Mapping for a Variable-Speed Ductless Heat Pump, *Proceedings of 13th International Refrigeration and Air Conditioning Conference at Purdue*, West Lafayette, Indiana (Link)

Report publications

Cheung, H., Braun, J. E. and Langner, M. R., (2016), *Methodology to Assess No Touch Audit Software Using Simulated Building Utility Data*, NREL/SR-5500-66001. Golden, CO: National Renewable Energy Laboratory (Link)

Cheung, H. and Braun, J. E., (2015), *Development of Fault Models for Hybrid Fault Detection and Diagnostics Algorithm*, NREL/SR-5500-65030. Golden, CO: National Renewable Energy Laboratory (Link)

AWARDS

The Hong Kong Polytechnic University Postdoctoral Fellowship, *The Hong Kong Polytechnic University* (2017)

Postdoctoral fellowship to support the research in developing data center energy management solutions.

3^{rd} ***Place Student Paper***, 15^{th} *International Refrigeration and Air Conditioning Conference Student Paper Competition* (2014)

Student paper competition awarded to student authors whose papers were well written and presented during the conference.

Ward A. Lambert Teaching Fellowship, *School of Mechanical Engineering, Purdue University, West Lafayette* (2013)

Ward A. Lambert Teaching Fellowship awarded to prospective students who aim at faculty positions in the future. The awardees followed a faculty mentor for a semester to develop their teaching skills, and became the lecturer of the same class in the next semester to gain teaching experience.

ASHRAE Graduate Student Grant-In-Aid, *American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)* (2011)

ASHRAE Graduate Student Grant-In-Aid awarded to graduate students whose research projects are beneficial to the ASHRAE community.

Academic Achievement Medal, *The Hong Kong University of Science and Technology* (2009)

Academic Achievement Medal awarded to undergraduate students who obtained a CGA higher than 10.75/12.00 at graduation and did not fail any classes during their undergraduate study.

Silver Award, President Cup, *The Hong Kong University of Science and Technology* (2009)

Silver Award, President Cup awarded to undergraduate students whose research projects show outstanding results. Projects from different disciplines such as science, engineering and social science were involved.

PRESENTATIONS

Siemens Energy Day (2014)

Presented a poster on the development of virtual power consumption and capacity for rooftop units to staff from Siemens, Inc. and Purdue University faculties and students, and obtained a second place in the energy consumption category.

Intelligent Building Operations Workshop 2013 (2013)

Presented 'Low-cost Virtual Power and Capacity Meter for Rooftop Units (RTU)' on the development of inexpensive virtual sensors for rooftop air-conditioning units.

PhD Symposium at University of Nebraska - Omaha (2013)

Presented the inverse modeling methodology of faulted vapor compression systems to faculties at the University of Nebraska and graduate students from other universities in the field of building research and construction management.

VOLUNTEERING

Technical Committee 1.1 Program Chair, *American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)* (2012 - 2017)

Organizing seminars on novel thermodynamic applications in air conditioning and refrigeration for the ASHRAE members during the Winter and Annual ASHRAE Conferences.

Reviewer, *Applied Energy, Applied Thermal Engineering, Energies, Energy and Buildings, International Journal of Refrigeration, Journal of Cleaner Production, Science and Technology for the Built Environment*

Reviewed more than 36 research papers submitted to the journals to decide if they can be accepted. Recognized as Oustanding Reviewer by International Journal of Refrigeration and Applied Thermal Engineering in 2015.

Student Member, Conference Organizing Committee, *Ray W. Herrick Laboratories, Purdue University* (2012 and 2014)

Assigning abstracts and papers of the biennial conference on HVAC equipment and buildings at Ray W. Herrick Laboratories to reviewers and presentation sessions and reviewing papers and abstracts.

Webmaster, *ASHRAE Purdue University Student Chapter* (2011 to 2012)

Maintaining the website of the local ASHRAE student chapter.

OPEN-SOURCE SOFTWARE

Data Preprocessing Helper (2017 - Present)

Developed for a graphical user interface for a tool to filter and re-structure dirty building management system (BMS) data.
Hosted and freely available at https://howardcheung.github.io/data-preprocessing-helper/

OpenStudio Fault Model (2014 - 2016)

Developed to create OpenStudio Ruby measure scripts to model impact of building faults on building energy consumption and thermal performance in the building simulation software OpenStudio.
Hosted and freely available at https://github.com/NREL/OpenStudio-fault-models