Contents

Conference Timetable 4
Plenary sessions and Informal Sessions 7
Keynote Speech 8
Plenary Session 10
Informal Sessions 14
Informal Session 01 : 15
Informal Session 02 : 16
Informal Session 03 : 17
Informal Session 04 : 19
Informal Session 05 : 20
Informal Session 06 : 22
Informal Session 07 : 23
Informal Session 08 : 24
Informal Session 09 : 25
Informal Session 10 : 26

Oral Session 27
Monday, 9th December, 10:45am ~ 12:00 pm 29
【DESIGN 01: Parametric Design】 29
【DESIGN 02: Automatic Design】 32
【DIGITAL 01: BIM & Digitalization of Building Practice】 35
【FUTURE 01: Urban-scale Simulation】 38
【HUMAN 01: Occupant Behavior】 41
【SYSTEM 01: Smart Building Applications】 44
【SYSTEM 02: HVAC system】 47

Monday, 9th December, 1:30pm ~ 2:45pm 49
【DESIGN 03: Weather and Climate】 49
【DESIGN 04: Parametric Design】 52
【DIGITAL 02: Big Data】 55
【FUTURE 02: District Energy System】 57

【HUMAN 02: Thermal Comfort】 59
【SYSTEM 03: Ventilation】 62
【SYSTEM 04: Cooling Optimization】 65

Monday, 9th December, 3:15pm ~ 4:30pm 68
【DESIGN 05: Envelope】 68
【DESIGN 06: Optimization of Design and Operation】 71
【DIGITAL 03: Advanced Modeling】 73
【FUTURE 03: Grid Integrated Building Design and Systems】 76
【HUMAN 03: Environmental Quality】 79
【SYSTEM 05: Daylight and Solar Shading】 82
【SYSTEM 06: Radiation】 85

Tuesday, 10th December, 10:45am ~ 12:00pm 90
【DESIGN 07: CFD and Airflow】 90
【DESIGN 08: Heat and Moisture】 93
【DIGITAL 04: Advanced Modeling】 96
【FUTURE 04: Urban-scale Simulation】 99
【HUMAN 04: Environmental Quality】 ROOM: OUN 7A 102
【HUMAN 05: Thermal Comfort】 105
【SYSTEM 07: HVAC System】 108

Tuesday, 10th December, 1:30 pm ~ 2:45pm 111
【DESIGN 09: CFD and Airflow】 111
【DIGITAL 05: Advanced Techniques】 113
【DIGITAL 06: Prediction】 116
【DIGITAL 07: Modelling and Application】 119
【HUMAN 06: Healthy Buildings】 122
【SYSTEM 08: Building Energy Systems】 125
【FUTURE 05: Demand Flexibility and Electrification】 128

Poster Session 130
Monday-Tuesday, 9th–10th December, 1:00pm ~ 1:30pm 131

Conference Timetable

Date: Sunday, 08/Dec/2024		
12:00pm	Technical Tour: Suma Sea World	
1:00pm - 6:00pm	Onsite Registration **Location: Plenary Hall**	
1:30pm - 3:30pm	Informal Session 01: Simulating and optimizing building-vehicle-grid interaction **Location: OUN 7A**	Informal Session 02: (Workshop) Surrogate modeling for multi-scale building performance simulation and its applications **Location: OUN 7B**
4:00pm - 5:30pm	Informal Session 03: Urban scale modeling to inform city planning of decarbonization and climate resilience **Location: OUN 10A**	
5:30pm - 7:30pm	Welcome Reception **Location: Plenary Hall**	

Date: Monday, 09/Dec/2024									
9:00am - 10:15am	PLENARY01: Opening and Keynote Speech **Location: Plenary Hall**								
10:15am	Coffee Break 1								
	SQ A	**SQ B**	**OUN 10A**	**OUN 10B**	**OUN 7A**	**OUN 7B**	**OUN 6A**	**OUN 6B**	**OUN 6C**
10:45am - 12:00pm	DESIGN 01: Parametric Design	DESIGN 02: Automatic Design	DIGITAL 01: BIM & Digitalization of Building Practice	FUTURE 01: Urban-scale Simulation	HUMAN 01: Occupant Behavior	SYSTEM 01: Smart Building Applications	SYSTEM 02: HVAC System	Informal Session 04: Path to Carbon Neutrality for Mega Cities: Focusing on Rating Methods	
12:00pm	Lunch and Coffee Break 1								
1:00pm - 1:30pm	POSTER: Face-to-Face Poster Session **Location: Plenary Hall**								

	SQ A	SQ B	OUN 10A	OUN 10B	OUN 7A	OUN 7B	OUN 6A	OUN 6B	OUN 6C
1:30pm - 2:45pm	DESIGN 03: Weather and Climate	DESIGN 04: Parametric Design	DIGITAL 02: Big Data	FUTURE 02: District Energy System	HUMAN 02: Thermal Comfort	SYSTEM 03: Ventilation	SYSTEM 04: Cooling Optimization	Informal Session 05: Indoor Green Building Simulation with OpenFOAM and BIM HVACTool	Informal Session 06: Visualizing invisible heat: analysis methods for radiant heat transfer
2:45pm	Coffee Break 2								
	SQ A	SQ B	OUN 10A	OUN 10B	OUN 7A	OUN 7B	OUN 6A	OUN 6B	OUN 6C
3:15pm - 4:30pm	DESIGN 05: Envelope	DESIGN 06: Optimization of Design and Operation	DIGITAL 03: Advanced Modeling	FUTURE 03: Grid Integrated Building Design and Systems	HUMAN 03: Environmental Quality	SYSTEM 05: Daylight and Solar Shading	SYSTEM 06: Radiation	Informal Session 07: Novel machine learning paradigms-enabled solutions for smart building energy modeling and management	
4:30pm	Move to Banquet Venue								
6:00pm	Sumiyoshi Taisha Shrine								
6:30pm	Banquet								

Date: Tuesday, 10/Dec/2024

9:00am	PLENARY02: Round-table discussion with representatives from each country **Location: Plenary Hall**								
10:15am	Coffee Break 3								
	SQ A	SQ B	OUN 10A	OUN 10B	OUN 7A	OUN 7B	OUN 6A	OUN 6B	OUN 6C
10:45am - 12:00pm	DESIGN 07: CFD and Airflow	DESIGN 08: Heat and Moisture	DIGITAL 04: Advanced Modeling	FUTURE 04: Urban-scale Simulation	HUMAN 04: Environmental Quality	HUMAN 05: Thermal Comfort	SYSTEM 07: HVAC System	Informal Session 08: CFD Applications in Building Performance Simulation and Beyond	

12:00pm	Lunch and Coffee Break 2								
1:00pm	POSTER: Face-to-Face Poster Session **Location: Plenary Hall**								
	SQ A	**SQ B**	**OUN 10A**	**OUN 10B**	**OUN 7A**	**OUN 7B**	**OUN 6A**	**OUN 6B**	**OUN 6C**
1:00pm				Informal Session 09: Bits4Watts 2024: International Workshop on Low-Carbon Building and Urban Energy Systems Powered by Data, AI, and Smart Controls					
1:30pm - 2:45pm	DESIGN 09: CFD and Airflow	DIGITAL 05: Advanced Techniques	DIGITAL 06: Prediction		DIGITAL 07: Modeling and Application	HUMAN 06: Healthy Buildings	SYSTEM 08: Building Energy Systems	FUTURE 05: Demand Flexibility and Electrification	Informal Session 10: Model-based control strategy and application
2:45pm	Coffee Break 4								
3:30pm	PLENARY03: Closing **Location: Plenary Hall**								
4:00pm - 6:00pm	Social Event **Location: Plenary Hall**								

Plenary sessions and Informal Sessions

Keynote Speech

Perspectives of Japan's Academic Leaders

Date : 9:20am ~ 10:45am, 9th December

Location : Plenary Hall (Congres Square Osaka Nakanoshima)

Moderator : Yohei Yamaguchi, Associate Professor,
Graduate School of Engineering, Osaka University.

At this plenary session, Japan's three academic leaders in the field of building performance simulation will be invited to share their perspectives on the potential for building performance simulation to contribute to solving social issues and the gaps that need to be filled through research and development. All the speakers have made significant academic contributions, as described below, that cover the key topics of ASim2024: simulating future metropolis, performance-driven designs, smart building systems, modeling for the digital world, and human-centered simulation/design.
The brief biographies of the speakers are as follows.

Yoshiyuki SHIMODA
Professor
Osaka University

Masaya OKUMIYA
Professor Emeritus
Nagoya University

Yasunori AKASHI
Professor
The University of Tokyo

Yoshiyuki SHIMODA, Professor, Osaka University

Prof. Yoshiyuki Shimoda is a professor at the Graduate School of Engineering at Osaka University. He has made significant contributions to the establishment of methods for modelling energy demand for building stock on a large scale. He pioneered approaches using building archetypes to reflect the building stock with detailed stock segmentation and representing all major end-uses by considering occupant behavior. This has made it possible to perform more detailed energy demand modeling of the building stock on a city to national scale considering a wide range of relevant building elements and dynamics. He has also excelled in the application of energy demand models to climate change mitigation and smart grid analysis. Some of his results have been cited in the sixth IPCC's Integrated Assessment Reports on Climate Change. He has been honored by several academic organizations in Japan. He has contributed to IBPSA as he served as the representative of IBPSA Japan Chapter from 2013 to 2023. In recognition of his contributions, he was appointed an IBPSA Fellow in 2023.

Masaya OKUMIYA, Professor Emeritus, Nagoya University

Prof. Masaya Okumiya is a Professor Emeritus at Nagoya University. His research on energy conservation and renewable energy utilization in buildings and cities is widely respected in Japan and abroad, especially in optimal design and control methodology for energy storage systems and associated simulation techniques. He developed predictive models for optimizing control and established optimal design and control methodology by extensive experimentation, demonstrations, and numerical analysis. His research is regularly implemented in both R&D and in practical applications in the design and control of advanced energy utilization systems and ZEBs. His contribution to IBPSA includes serving as the secretariat representative for the 7th International Conference (BS99) of the IBPSA (held in Kyoto in 1999). He also invited the 2nd Asian Regional Conference on Simulation of Building Performance (ASIM2014) to Nagoya University (in 2014) while serving as the conference chairman. In addition, he was the IBPSA Japan Chapter President from 2013-2022.

Yasunori AKASHI, Professor, The University of Tokyo

Prof. Yasunori Akashi obtained the Degree of Dr. Eng. from UTokyo in 1996 and he was promoted to Associated Professor in 1998 and a Professor in 2009 at Kyushu University. He moved to UTokyo as a Professor in 2013, to present. He studied at LBNL, USA from 2000 to 2001. Today, he is promoting a wide range of research projects including (1) energy systems for smart buildings, (2) human-centric new indoor environments and behavior changes, (3) renewable energy utilization and energy coordination, (4) resilience and management of building service systems, (5) development of new elemental technologies and evaluation methods for building environments and services, and (6) quantification of policy effects to support stakeholders' decision-making. He serves on a number of related academic and government committees and plays a key role for the Campus GX of UTokyo. As a contribution to society, he was a President of the Japanese Association of Building Mechanical and Electrical Engineers in 2020-2023, and currently he is a Vice President of the Building Services Commissioning Association, and a President of the Japan Association of Energy Service Companies.

Plenary Session

Challenges and Perspectives for the Futures

Date : 9:00am ~ 10:15am, 10th, December

Location : Plenary Hall (Congres Square Osaka Nakanoshima)

Moderator : Yohei Yamaguchi, Associate Professor, Graduate School of Engineering, Osaka University.

ASim is a series of conferences organized by IBPSA affiliates in Asia. Countries in Asia share similar meteorological conditions and social contexts. However, their building stock and building projects differ significantly in various aspects, such as physical characteristics, configuration and performance of building systems, and operation and utilization. Reflecting on both these commonalities and differences can help facilitate the mutually beneficial exchange of ideas to address pressing social issues through the use of building performance simulation.

This plenary session will invite representatives of IBPSA affiliates to share their experiences and perspectives on relevant areas, as well as the contribution of building performance simulation to social issues at the national or international levels. The session will start with a series of short presentations by the representatives of IBPSA affiliates in Asia listed below. Two participants from IBPSA-USA and IBPSA-England will then provide their reflections on the comments made by the speakers. This will be followed by an open discussion on the challenges and gaps to be filled.

Moderator

IBPSA-Japan	Yohei Yamaguchi, Osaka University

Affiliate representatives

IBPSA-China	Da Yan, Tsinghua University
IBPSA-Korea	Cheol-Soo Park, Seoul National University
IBPSA-Singapore	Adrian Chong, National University of Singapore
IBPSA-Indonesia	Rizki Armanto Mangkuto, Institut Teknologi Bandung
IBPSA-India	Vishal Garg, Plaksha University

Reflections

IBPSA-USA	Tianzhen Hong, Lawrence Berkeley National Laboratory
IBPSA-England	Ruchi Choudhary, University of Cambridge

Moderator and speakers

Yohei Yamaguchi, Osaka University

Dr. Yohei Yamaguchi has been the Director of IBPSA Japan since 2023. He has been engaged in research on energy management and climate change mitigation in residential and non-residential building stock since 2001, when he began his master's program. He has developed methods for modeling energy demand of building stock, which are called the building stock energy modeling (BSEM) and urban building energy modeling (UBEM). His research interests include modeling and analysis of human behavior, technology adoption and implementation, and climate change mitigation.

Masato Miyata, National Institute for Land and Infrastructure Management
Dr. Masato Miyata is a senior researcher at the National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan. He specializes in research and development focused on achieving decarbonization and energy efficiency in non-residential buildings through the application of energy simulation techniques. He has been involved in the development of calculation methods and online tools for assessing primary energy consumption in accordance with Japan's building energy standards. Since 2014, he has served as the convener of ISO/TC205 "Building Environment Design" WG10 "Commissioning," contributing to the standardization of commissioning processes in building design and operation.

Da Yan, School of Architecture, Tsinghua University
Dr. Yan is a full Professor from School of Architecture, Tsinghua University. He is the Editor-in-chief of Building Simulation and Section Editor of Energy and Buildings. He is also the Chair of China HVAC Society's Building Simulation Committee, Chair of IBPSA-China, IBPSA Fellow and Chair of ASHRAE TC 7.10 on Occupant Behavior in Building. Professor Yan mainly focuses on the development of building performance simulation software DeST, modelling of occupant behavior, and low-carbon and energy-efficiency related policy. During 2013 to 2018, he was the OA of IEA EBC Annex 66 with more than 100 participants from more than 20 countries, working on "Definition and simulation of occupant behavior in buildings". He has published over 240 journal articles and more than 10 books, with an H-index of 57 (by google).

Cheol-Soo Park, Seoul National University
Professor Cheol-Soo Park has achieved significant contributions through research, education, and numerous honors. Professor Park's career spans impactful positions including serving as the 15th president of the Korean Institute of Society of Architectural Sustainable Environment and Building Systems (KIAEBS), the chair of IBPSA-world awards and fellows committee, and a member for the Korea's presidential advisory council on science & technology. His academic dedication to the field of building simulation is evident through his extensive publication record and the mentoring of students who have achieved prestigious awards under his guidance. His recent research interests include MPC for real-life cases, physics-informed AI, federated learning model, causality-based model, model calibration, and occupant behavior.

Adrian Chong, National University of Singapore (NUS)
Adrian Chong is an Associate Professor at the National University of Singapore (NUS) and an IBPSA Fellow. His research focuses on optimizing building energy efficiency, particularly in mixed-mode ventilation for the Tropics, model calibration, uncertainty quantification, and occupant-centric controls. He leads the Integrated Data, Energy Analysis, and Simulation (IDEAS) lab at NUS, exploring the intersection of building performance simulation, measured data, and machine learning. Adrian serves as a subject editor for Building Simulation, an editorial board member for Energy and Buildings, and an Early Career Board Member for Building and Environment.

Rizki Armanto Mangkuto, Institut Teknologi Bandung
Dr. Rizki A. Mangkuto is associate professor at the Department of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Bandung, Indonesia. He holds BSc (2006) and MSc (2009) degrees from the same department and university, and PhD degree (2014) from the Unit Building Physics and Services, Department of the Built Environment, Eindhoven University of Technology, the Netherlands. His research interests are lighting engineering, computational building performance simulation, and building physics in general. He is currently the chair of Built Environment Performance Engineering Research Group and the head of Lighting Laboratory at his department. He holds a professional engineer certificate from the Indonesian Institute of Engineers and is a certified lighting practitioner from the Indonesian Illuminating Engineering Society. He also currently serves as the secretary of the Indonesian chapter of the International Building Performance Simulation Association (IBPSA Indonesia).

Vishal Garg, Plaksha University
Dr. Vishal Garg is a University Chair Professor and the Director of Indorama Ventures Center for Clean Energy. He works on various aspects of energy efficiency in buildings, such as building energy simulation for designing energy-efficient buildings and automation and controls for efficient operations. His current focus is on Smart Energy Homes. He is developing and field testing a Smart Home Energy Management System (SHEMS) to understand its impact on energy savings and demand reduction. This work also includes psychological evaluations and sociological approaches to understanding people’s energy behaviour. He is also involved in policy-making and market research of smart energy homes and is incubating a start-up to facilitate lab to market.

Tianzhen Hong, Lawrence Berkeley National Laboratory, USA
Dr. Tianzhen Hong is Deputy Director for Research and Senior Scientist with the Building Technology and Urban Systems Division of Lawrence Berkeley National Laboratory, USA. His research employs interdisciplinary approaches to explore technologies and human behavior strategies supporting the planning, design and operation of energy efficient, demand flexible, and climate resilient buildings and communities. He leads the EnergyPlus development at LBNL and his simulation software CBES and CityBES won the R&D 100 awards in 2019 and 2022. He is an IBPSA Fellow and ASHRAE Fellow. He published 217 journal articles and has been a Highly Cited Researcher since 2021.

Ruchi Choudhary, University of Cambridge
Dr. Ruchi Choudhary is Professor of Architectural Engineering in the Engineering Department at University of Cambridge. She specializes in simulation methods for predicting energy demand of the built environment. At Cambridge, she leads the multi-disciplinary Energy Efficient Cities Initiative, initially funded by a Science & Innovation award at Cambridge. She is leading projects on modelling underground heat and city-scale geothermal systems, district energy networks, urban-integrated farming, and end-use energy demand in buildings. In 2019 she became fellow of the International Building Performance & Simulation Association (IBPSA). She is on the editorial board of J. of Building Performance Simulation, BSER&T the CIBSE Journal, Sustainable Cities and Society, and ICE J. of Smart Infrastructure & Construction.

Informal Sessions

Date: Sunday, 08/Dec/2024	
1:30pm – 3:30pm, Location OUN 7A **Informal Session 01：** Simulating and optimizing building-vehicle-grid interaction	**1:30pm – 3:30pm, Location OUN 7B** **Informal Session 02：** Surrogate modeling for multi-scale building performance simulation and its applications
4:00pm – 5:30pm, Location OUN 10A **Informal Session 03：** Urban scale modeling to inform city planning of decarbonization and climate resilience	
Date: Monday, 09/Dec/2024	
10:45am – 11:30am, Location OUN6B **Informal Session 04：** Path to Carbon Neutrality for Mega Cities: Focusing on Rating Methods	
1:30pm – 2:45pm, Location OUN6B **Informal Session 05:** Indoor Green Building Simulation with OpenFOAM and BIM HVAC Tool	**1:30pm – 2:45pm, Location OUN6C** **Informal Session 06:** Visualizing invisible heat: analysis methods for radiant heat transfer
3:15pm – 4:30pm, Location OUN6B **Informal Session 07:** Novel machine learning paradigms-enabled solutions for smart building energy modeling and management	
Date: Tuesday, 10/Dec/2024	
10:45am – 12:0pm, Location OUN6B **Informal Session 08:** CFD Applications in Building Performance Simulation and Beyond	
1:00pm – 2:45pm, Location OUN10B **Informal Session 09:** Bits4Watts 2024: International Workshop on Low-Carbon Building and Urban Energy Systems Powered by Data, AI, and Smart Controls	**1:30pm – 2:45pm, Location OUN6C** **Informal Session 10:** Model-based control strategy and application

Informal Session 01：

Session title	**Simulating and optimizing building-vehicle-grid interaction**
Time	1:30pm – 3:30pm, 8th Dec.
Location	OUN 7A
Keywords	Building-vehicle-grid interaction, smart grid, electric vehicle
Highlights	• Given the growing popularity of electric vehicles, the interplay among buildings, electric vehicles, and the power grid has gained significant importance in establishing a versatile, efficient, and intelligent energy infrastructure. • The objective of this session is to facilitate the exchange of research pertaining to the modeling and optimization of the interaction between buildings, electric vehicles, and the power grid.
Session description	With the increasing prominence of electric vehicles (EVs) and the pressing need for sustainable energy solutions, understanding and improving the dynamic relationship between buildings, EVs, and the power grid has become of paramount importance. The seminar aims to foster an environment for knowledge exchange and collaboration among researchers, industry experts, and policymakers in the field of energy systems and sustainable transportation. By bringing together experts from various disciplines, we will explore the latest advancements in modeling and optimizing the intricate interplay between buildings, EVs, and the power grid. By the end of the session, participants will have a deeper understanding of the state-of-the-art modeling and optimization techniques for more efficient building-vehicle-grid interaction, and will be able to identify existing gaps that need to be addressed in future research and development.
Presenters	The presentation titles are to be determined. The following presenters agree to give a talk in this session: • Borong LIN, Tsinghua University • Zhe WANG, The Hong Kong University of Science and Technology • Weirong ZHANG, Beijing University of Technology • Shiming TIAN, China Electric Power Research Institute • Yang GENG, Tsinghua University

Informal Session 02：

Session title	Surrogate modeling for multi-scale building performance simulation and its applications
Time	1:30pm – 3:30pm, 8th Dec.
Location	OUN 7B
Keywords	Surrogate modeling, building performance simulation, energy modeling, wind modeling, generative modeling, Artificial Intelligence
Highlights	Participants will • Understand the basics of surrogate modeling and its applications in building performance simulations • Try hands-on activities with prepared files, using a campus model as test-case • Run various simulations including energy, airflow, and other associated metrics
Session description	This workshop will introduce participants to the fundamentals of surrogate modeling and its applications in multi-scale building performance simulation. Surrogate models are computationally efficient approximations of complex, high-fidelity simulation models, enabling faster design space exploration and optimization. During the workshop, participants will gain an understanding of the basics of surrogate models, their use cases, and applications in building performance simulation. They will explore surrogate modeling for energy and wind analysis using Python in Google Colab, Rhino3D, and Grasshopper. Participants will engage in hands-on activities using prepared files and a provided campus model as a test case, allowing them to run various simulations, including energy and wind analyses, and gain practical experience with surrogate modeling techniques. The workshop will also discuss the potential benefits and applications of surrogate modeling in building performance simulation, as well as various methods suitable for different use cases. This will include topics such as design optimization and real-time performance prediction. By the end of the workshop, participants will have a good foundational understanding of surrogate modeling techniques and their applications in multi-scale building performance simulation. They will be equipped with the knowledge and skills necessary to implement surrogate models in their own projects, enabling more efficient and effective design processes. Workshop followed by the lecture. Integrated workflow: Rhino and Grasshopper and Colab/Jupyter Notebook Requirements Bring your laptop with Rhino, Grasshopper installed and Google Colab if interested to follow along. A Google Drive with workshop files will be provided prior to the workshop.
Presenters	• Jung Min Han, Yonsei University • Yu Qian Ang, National University of Singapore

Informal Session 03：

Session title	Urban scale modeling to inform city planning of decarbonization and climate resilience
Time	4:00pm – 5:30pm, 8th Dec.
Location	OUN 10A
Keywords	urban building modeling, urban energy system, decarbonization, climate resilience, building simulation
Highlights	• UBEM is a powerful modeling and simulation technique to provide insights informing city decision making on building energy use, decarbonization, building climate resilience, and urban environment sustainability. • Four presentations highlight recent research on UBEM for cities in USA and China. The approaches can be adopted for other cities and countries.
Session description	This session showcase recent interesting research of using urban scale modeling to assess urban wind environment, building energy performance, building resilience, and anthropogenic heat from buildings in cities. Four presentations are: Title: A downscaling prediction method of wind environment suitable for urban building energy consumption analysis Abstract: Urban microclimate changes have a great impact on building energy consumption. The setting of boundary conditions in numerical simulation affects the accuracy of wind environment simulation. However, urban morphology is complex, and commonly used downscaling simulation methods are time-consuming and computationally intensive. In response to the above issues, this study proposes an ANN-based wind environment downscaling prediction model based on prototype block models (PBMs). The PBMs model established in the study takes into account the urban morphological factors that affect the characteristics of the urban wind environment. The ANN model is used to extract the CFD wind speed simulation results of BMPs, thereby saving computing time. Taking the Nanjing area as an example, by comparing the predictive performance under 15 combinations of explanatory variables, the effectiveness of the proposed method was validated. Title: Assessing building stock resilience to extreme cold weather based on urban building energy modeling Abstract: Climate change and expected extreme weather conditions have raised significant concerns, particularly regarding the energy supply for urban buildings. In cities with district heating, high-resolution simulations of building energy demand are crucial for efficient energy allocation and scheduling. However, variations in building age and envelope degradation make it difficult to capture thermal properties accurately. Additionally, spatial weather differences in the urban area impact energy demand. This study proposes a novel UBEM approach to assess building stock resilience, considering the distribution of envelope thermal properties and microclimate conditions. A validated UBEM of Beijing is established and building resilience to future cold waves and retrofit strategies are analyzed. The results show that the approach effectively produces high-resolution energy demand analyses during extreme weather. Title: Urban building energy modeling based on a modularized neural network incorporating physical priors

	Abstract: Bottom-up UBEM models require detailed building information and substantial modeling effort, while top-down models cannot intrinsically predict future trends and provide only aggregated data without precise spatial or temporal detail. To improve the scalability and the reliability of bottom-up models, this study proposes a modularized neural network incorporating physical priors, offering an effective solution for urban-scale building energy modeling. The integration of physical constraints ensures accurate responses to varying conditions. The proposed model demonstrates high accuracy in energy demand calculations. Title: Integrating urban building energy modeling with urban microclimate modeling to quantify the anthropogenic heat from buildings and its impact on urban environment Abstract: Anthropogenic heat (AH) from buildings increases urban air temperature and contributes to the urban heat island effect. Building AH exhibits strong seasonal and diurnal patterns with large spatial variations. Building AH peaks in May and reaches a maximum of 878 W/m2, with higher AH attributed to large building density, a high percentage of industrial buildings, and older building stock. During the July 2018 heatwave in LA County, building AH leads to a daily max and min ambient temperature increase of up to 0.6 ◦C and 2.9 0.6 ◦C respectively. It is recommended that reducing summer building AH should be considered by policy makers in developing mitigation measures for cities to transition to clean energy while improving heat resilience.
Presenters	• Prof. Da Yan, Tsinghua University, China. Assessing building stock resilience to extreme cold weather based on urban building energy modeling; • Prof. Bing Dong, Syracuse University, USA. Urban building energy modeling based on a modularized neural network incorporating physical priors; • Dr. Xin Zhou, Southeast University, China. A downscaling prediction method of wind environment suitable for urban building energy consumption analysis; • Dr. Tianzhen Hong, LBNL, USA. Integrating urban building energy modeling with urban microclimate modeling to quantify the anthropogenic heat from buildings and its impact on urban environment.

Informal Session 04：

Session title	**Path to Carbon Neutrality for Mega Cities: Focusing on Rating Methods**
Time	10:45am – 11:30am, 9th Dec.
Location	OUN6B
Keywords	Carbon neutral, Energy rating system, Data uncertainty, Inverse Modeling, Mixed use and building type
Highlights	• In this session, we will hear from experts and gather audience opinions on achieving carbon neutrality in mega cities. • We'll discuss strategies for reducing and offsetting carbon emissions with help of energy rating systems. • We'll also address data uncertainty and its impact on building assessments and decision-making. • Additionally, we like to discuss on inverse modeling by inferring unknown parameters from observed data.
Session description	In this session, we will hear from experts and collect audience opinions on important topics related to sustainable building practices and energy management, particularly focusing on achieving carbon neutrality in mega cities. We like to discuss on strategies to reduce and offset carbon emissions using the energy rating system to evaluate and compare the energy performance of buildings. The session introduced the new policy by Seoul City for achieving net zero and how the rating method was used for implementing the policy. We also explore inverse modeling, a technique used to infer unknown parameters based on observed data, which is crucial for improving building performance indicators. The session also aims to address and gather insights on data uncertainty, highlighting how variability and inaccuracies in data can impact building assessments and decision-making. Finally, we engage with attendees to explore how building energy tools can support the policy and examine the limitations of current methods.
Presenters	• Dr. Yun Kyu Yi, University of Illinois at Urbana-Champaign, USA • Dr. Hyoungsub Kim, Inha University, South Korea • Dr. Hansol Lim, Korea Institute of Civil Engineering and Building Technology, South Korea

Informal Session 05：

<table>
<tr><td>Session title</td><td>Indoor Green Building Simulation with OpenFOAM and BIM HVACTool</td></tr>
<tr><td>Time</td><td>1:30pm – 2:45pm, 9th Dec.</td></tr>
<tr><td>Location</td><td>OUN6B</td></tr>
<tr><td>Keywords</td><td>OpenFOAM, BIM HVACTool, CFD, Indoor Simulation</td></tr>
<tr><td>Highlights</td><td>Setting up an indoor simulation for OpenFOAM using BIM HVACTool
Demonstrating all necessary steps for the simulation process
Focusing on thermal comfort evaluation
Showcasing the workflow from BIM model to CFD analysis
Explaining key parameters and settings for accurate results
Visualize the simulation results using ParaView and render them with NVIDIA Optix</td></tr>
<tr><td>Session description</td><td>This session will demonstrate the setup of an indoor simulation for OpenFOAM using BIM HVACTool software. We will guide you through all necessary steps in the simulation process, focusing particularly on evaluating thermal comfort. The demonstration will cover the entire workflow, from the initial BIM model to the CFD analysis. Throughout the session, we will explain key parameters and settings crucial for accurate results. Additionally, we will show how to visualize the simulation results using ParaView and render them with NVIDIA Optix, providing a comprehensive overview of the thermal comfort assessment and visualization process in building design.</td></tr>
<tr><td>Presenters</td><td>Dr. Alex Lee, Managing Director TIAN Building Engineering (Co-Founder of BIM HVACTool)</td></tr>
<tr><td>Instructions/Notes for Participants</td><td>Pre-Workshop Preparation

1. Software Installation
Please download the following software installers from the provided DropBox link:
BIM HVACTool Client
BIM HVACTool Fluid
ParaView
Additional required tools (details included in the DropBox link).
DropBox Link:
https://www.dropbox.com/scl/fo/ayne5vwxsg4w8n3asuum1/AHO_-2GPz_lREHKVHnje5t4?rlkey=sowgfg5l5mgprqk58ttqu2gci&dl=0

2. Demo License Key Activation
Upon installation, activate the 30-day free demo license key.
Instructions for activation are included in the installer package documentation.
After activation, please send your Name and Email to Dr. Alex Lee at alex.lee@building-engineering.sg. This will help us confirm your preparation and provide any necessary updates before the workshop.
3. Hardware Requirements
To ensure smooth operation of the tools during the workshop:
Operating System: Windows 10 or above.
Graphics Card: NVIDIA RTX 3070, is recommended.
RAM: 64 GB of RAM or more is preferable.
4. Bring Your Own Computer & Mouse
Participants are required to bring their own laptop with all the nec-essary</td></tr>
</table>

	software installed and the demo license activated prior to the session. This will ensure you can actively participate in the hands-on exercises without delays. 5. Workshop Agenda • Overview of BIM HVACTool and OpenFOAM for Green Building Simulations. • Step-by-step guidance on using BIM HVACTool for indoor simulations. • Visualization and analysis with ParaView. 6. Technical Support If you encounter any issues during installation, feel free to reach out to alex.lee@building-engineering.sg ____ We look forward to your participation and an engaging session on advanced simulation techniques.

Informal Session 06：

Session title	**Visualizing invisible heat: analysis methods for radiant heat transfer**
Time	1:30pm – 2:45pm, 9th Dec.
Location	OUN6C
Keywords	Heating and cooling, radiant systems, sensors, thermal comfort
Highlights	• Review the basics of heat transfer and thermal comfort characterization • History of measurements of thermal comfort variables: temperature, humidity, air movement, thermal radiation • Advanced techniques for measuring radiant heat transfer • Deep dive on radiant heat transfer spatial and temporal variations • Challenges in using temperature proxies such as Mean Radiant Temperature and Operative Temperature • The concept of a human-centric heat transfer analysis for rooms: the Human Coefficient of Performance (HCOP)
Session description	Achieving thermal comfort is the end goal of heating and cooling systems installed in buildings. Yet these systems rely limited feedback from thermostats that generally only measure air temperature. Historically the concept of thermal comfort is relatively new, and actually evolved out of occupational health studies of heat endurance. Many measurement devices and techniques, including the globe thermometer for radiant heat, are vestiges of studies of heat resilience in factories by doctors in the 1920's and 1930's. Since Fangers seminal work in the 1970's building comfort models that include inputs from the 4 key environmental variables, temperature, humidity, air speed, and radiant temperature, researchers have strived to achieve good scores of his metrics of PMV and PPD. But these metrics still use the old tools of globe thermometers and Mean Radiant Temperature. This workshop will present new tools and techniques for measuring radiant heat transfer, and expose participants to the significant and overlooked variation of radiant heat across small spaces and short periods of time. This spatial and temporal heterogeneity can only be measured with new tools, and demonstrates significant opportunities to reconsider how radiant heat can be used to create more nuanced control beyond the coarse zones of standard air conditioning. We will discuss how a Watts-based approach to thermal comfort can offer additional insights to human comfort that go beyond the Fanger's statistics, and take advantage of contemporary microprocessor hardware and computational power. Participants will come away with a new perspective on how we define the performance of heating and cooling systems – one that moves away from the failed paradigm of making rooms comfortable, and aims at making people comfortable. In the end the performance of building should not be based on performance normalized by floor area as in EUI, but rather the people whose heat transfer is managed most effectively with the least energy.
Presenters	• Forrest Meggers, Associate Professor, Director of CHAOS, Princeton University • Ippei Izuhara, President, GET/ General Manager, Sanken/ Visiting Fellow, Princeton University • Kianwee Chen, Environmental Technology Senior Researcher, GET/Sanken • Clayton Miller, Associate Professor, National University of Singapore • Genku Kayo, Associate Professor, Tokyo City University

Informal Session 07：

Session title	**Novel machine learning paradigms-enabled solutions for smart building energy modeling and management**
Time	3:15pm – 4:30pm,9th Dec.
Location	OUN6B
Keywords	Machine learning; Smart building operation; Large language models; Data-driven models; Building energy management.
Highlights	• Introduction of typical data-driven solutions for building energy modeling and management. • Discussion on practical data challenges faced in building energy modeling and management together with the potentials of novel machine learning paradigms. • Applications of novel machine learning paradigms for smart building operations.
Session description	The rapid development in AI and machine learning has provided powerful tools to facilitate tasks in building energy modeling and management. This workshop focuses on introducing the potentials of novel machine learning paradigms in enhancing the working efficiency of building specialists and addressing possible data challenges in practice. As examples, invited speakers will talk about the use of large language models to achieve automated building energy modeling, which can greatly reduce the manual labors in software simulation. Other speakers will talk about solutions related to the development of reliable data-driven models for building energy management tasks such as short-term building energy prediction, fault detection and diagnosis, e.g., using semi-supervised learning to enhance model quality given limited labeled data, and applying transfer and federated learning to integrate multi-source building energy data for collaborative model training.
Presenters	• Linda Fu Xiao, Professor, The Hong Kong Polytechnic University • Jianli Chen, Professor, Tongji University • Ke Yan, Professor, Hunan University • Marco Savino Piscitelli, Assistant professor, Polytechni di Torino • Cheng Fan, Associate professor, Shenzhen University

Informal Session 08：

Session title	**CFD Applications in Building Performance Simulation and Beyond**
Time	10:45am – 12:0pm, 10th Dec.
Location	OUN6B
Keywords	Computational fluid dynamics (CFD); airflow simulations; best practice guideline; lesson learnt
Highlights	• Introduction to CFD in building performance simulation - Overview of the role of CFD in analyzing airflow, thermal comfort, indoor air quality, and energy efficiency in buildings. • Lessons learned from real-world case studies - Present a selection of case studies that showcase the application of CFD in building performance simulation, focusing on the successes, challenges, and lessons learned. • Best practices and guidelines for CFD simulations - Discuss key considerations, methodologies, and approaches for achieving accurate and reliable CFD simulations in building performance analysis. • Overcoming challenges in CFD simulations - Explore the limitations, potential pitfalls, and common challenges faced in CFD simulations, and provide strategies and solutions to overcome them. • Q&A and open discussion for participants to seek clarification, share their experiences, and gain insights.
Session description	The application of Computational Fluid Dynamics (CFD) in building performance simulation has gained significant importance in achieving sustainable and energy-efficient buildings. However, there are various challenges and considerations that need to be addressed to ensure accurate and reliable results, from grid generation to selection of boundary conditions as well as from model validation to result analysis. This session will provide a platform for sharing lessons learned and best practices in utilizing CFD for building performance simulation, enabling practitioners to enhance their understanding and improve their approach in this field. Through this session, we hope to: (1) Increased awareness of the successes, challenges, and lessons learned from real-world CFD applications in building performance simulation. (2) Improved understanding of best practices and guidelines for utilizing CFD effectively in building performance analysis. (3) Identification of potential pitfalls and challenges in CFD simulations and strategies to overcome them. (4) Enhanced collaboration and knowledge exchange among researchers, practitioners, and industry professionals in the field of CFD for building performance simulation.
Presenters	• Yoshihide Tominaga (Niigata Institute of Technology) • Zitao Jiang (Niigata Institute of Technology) • Lup Wai Chew (National University of Singapore) • Janssen Xing Zheng (City University of Hong Kong)

Informal Session 09：

Session title	**Bits4Watts 2024: International Workshop on Low-Carbon Building and Urban Energy Systems Powered by Data, AI, and Smart Controls**
Time	1:00pm – 2:45pm, 10th Dec.
Location	OUN10B
Keywords	Building and urban energy systems; Building decarbonization; Machine learning; Smart controls; Data analytics
Highlights	• 6 presentations by colleagues from Hong Kong, Italy, Japan, Singapore, and the UK • Recent developments and demonstrations of data management, artificial intelligence, model-based diagnostic and control technologies, and grid interactions
Session description	Digitalization is becoming increasingly crucial in making today's buildings low-carbon and energy-efficient. According to the International Energy Agency, utilizing the data from ubiquitous sensors, actuators, and IoT devices could save around 10% of energy use in residential and commercial buildings by 2040. By leveraging data and data-driven techniques, various stakeholders can gain valuable insights and make better decision-making throughout all phases, from design through construction to operations. This workshop aims to explore the integration of data, AI, and advanced controls in building energy management from individual buildings to the community scale. The workshop will feature selected presentations of case studies that highlight recent developments and demonstrations of data management, artificial intelligence, model-based diagnostic and control technologies, and grid interactions. The format will encourage an open discussion to address what is necessary to move from research to the widespread adoption of smart data-driven building technologies. By the end of the workshop, participants will have a deeper understanding of the current state of smart data-driven technologies in buildings and will be able to identify existing gaps that need to be addressed in future research and development. For more information, visit the workshop website at https://bits4watts.org/.
Presenters	• Ruchi Choudhary, Professor, Cambridge University, UK • Alfonso Capozzoli, Professor, Polytechnic University of Turin, Italy • Linda Xiao, Professor, The Hong Kong Polytechnic University, Hong Kong • Shohei Miyata, Project Lecturer, The University of Tokyo, Japan • Zhe Wang, Assistant Professor, The Hong Kong University of Science and Technology, Hong Kong • Maomao Hu, Assistant Professor, National University of Singapore, Singapore

Informal Session 10：

Session title	Model-based control strategy and application
Time	1:30pm – 2:45pm 10th Dec.
Location	OUN6C
Keywords	High-fidelity simulation, Model calibration, Control strategy, Engineering application
Highlights	• Development of high-fidelity simulation platform of building energy system • Generation and validation of building energy system operation strategies based on high-fidelity modelling
Session description	Under the background of low carbonization, the building energy is transforming to the system integrated with cooling, heating and power supply, which is more and more complex. On the other hand, the external energy price fluctuations are becoming more and more frequent, which brings more difficulties to the operation and maintenance of the system. With the high-fidelity simulation model system that fully reflects the actual dynamic feature of building energy system, it is feasible for researcher or engineer to optimize and generate control strategies online or offline for the system under the diverse conditions of different energy price policies, such as time-of-use power price or demand side response power price, etc. Besides, the HVAC control strategy optimization is a hot topic of study with the development of artificial intelligent technologies. A lot of control strategies is generated based on model or model-free technology. But them are seldom applied to real practical engineering. Lack of the tool to test the performance and reliability before engineering application is main reason. Then, developing the full-performance building energy system simulation platform is considered to be the important research of simulation engineering application. In order to realize the above research concepts, there are a long way to go. The following questions are expected to answer: 1.What kind of simulation model should be built? 2.How to achieve the high fidelity of the simulation model? 3.How to balance the computational efficiency and accuracy in the process of strategy optimization? 4.How to break through the barrier between the study results and the application. That is, how to apply the simulation strategy into the engineering application? 5.How about the application performance of optimized strategy generated by simulation in the actual project? 6.And so on… This session proposed hopes to gather researchers in the direction to exchange research ideas, technical routes and engineering application case study, promote the development of simulation modeling in the field of building energy, and better serve and support engineering practice.
Presenters	Dr. J.D. Niu Assoc prof. Y. Ding Assoc prof. X. C. Yang Prof. J.Z. Ma Prof. J.Q. Peng Dr. J.J. Jiang

Oral Session

Monday, 9th December

Monday, 9th December, 10:45am ~ 12:00 pm

【DESIGN 01: Parametric Design】

9th December, 10:45am ~ 12:00 pm

Session Chair: Sun-Sook Kim, Ajou University

Session Chair: Yusuke Arima, Kyushu University

A Grasshopper-based parametric simulation of microclimate and thermal comfort in a Cfa-climate campus playground

Jing Xiao[1], Ruixuan Li[2], Lin Li[3], Chong Liu[4]
[1]Zhejiang normal university, China, People's Republic of; [2]Dalian Polytechnic University,China, People's Republic of; [3]Japan Advanced Institute of Science and Technology, Japan; [4]Japan Advanced Institute of Science and Technology, Japan

A low-risk campus playground raises activity frequency and physical health. Taking a campus playground of Zhejiang Normal University as a case study, we use Rhino and Grasshopper tools integrated modeling-analysis-simulation process that explores the potential thermal risks and design flaws of a high-frequency active campus playground. The annual Universal Thermal Climate Index (UTCI) results showed that April and October are the best times to hold the Spring and Autumn Games. The hottest months were mid-July to early August at the campus playground concentrated at over 50% of very hot levels during the day and up to over 75% of moderate hot levels at night. The simulated flow of pedestrians revealed that the east-west direction is the preferred direction for pedestrians to walk from the entrance to the center area of the lawn, with fewer artificial shading devices in the east-west direction where direct sunlight lasted for the longest time suggesting add-in the shading facilities and green shade to reduce exposure risks. This cross-simulation mechanism and data reference for the revision of design strategies in automated tools and customized scripts to get sustainable design solutions for many designer users.

Influential Design and System Operation for Energy Consumption and Daylight Utilization: Case Study High School in Makassar, Indonesia

Yuniar Afifa Nur, Gyuyoung Yoon
Nagoya City University, Japan

According to Indonesian Law Number 32, in 2009, the Indonesian Government participated in implementing energy efficiency for the implementation of sustainable development. As Indonesia's education system is the fourth largest in the world, school buildings have a significant social responsibility, making the energy performance in this type of building of great importance. In addition, promoting energy efficiency in school buildings means targeting the young generation for sustainable development awareness. This study collected data from 28 school high schools in Makassar, the capital city of south Sulawesi; it is a city with an average 15% per year growth rate of electricity demand and is considered one of the highest average cities in Indonesia in terms of energy demand. The data collected was analyzed to understand the typical school building and existing challenges for reducing energy consumption. Accordingly, the typical building geometry and site plan condition were generated and modeled on

energy simulator TRNSYS 18 to understand the energy consumption and energy saving potential. Results shows that large WWR could decrease energy consumption of typical school building by 21.3% and North orientation could have more energy savings compared to other orientations for the total energy consumption.

The Influence of Sample Size on the Robustness of Sensitivity Analysis Results in Building Performance Simulation

Arinda P. Rachman[1], Rizki A. Mangkuto[2], M. Donny Koerniawan[3], Joko Sarwono[2]
[1]Engineering Physics Program, Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung, Indonesia; [2]Built Environment Performance Engineering Research Group, Faculty of Industrial Technology, Institut Teknologi Bandung, Bandung, Indonesia; [3]Building Technology Research Group, School of Architecture, Planning and Policy Development, Institut Teknologi Bandung, Bandung, Indonesia.

Sensitivity analysis (SA) is essential for understanding how input variables influence the output of complex models. However, the robustness of SA results is often influenced by sample size, and the precise impact of sample size on the reliability and stability of these results remains underexplored. This study examines the effect of varying sample sizes on the robustness of sensitivity analysis, focusing on the stability of Standardized Regression Coefficients (SRC) and the ranking of design alternatives.

We conducted a series of building performance simulations on a typical commercial building model in Jakarta. The model includes 16 design variables (n) and four performance metrics: Energy Use Intensity (EUI), Percentage of Comfort Hours (PCH), Spatial Daylight Availability (sDA300,50%), and Annual Sunlight Exposure (ASE1000,250). Different sample sizes were tested to observe their impact on sensitivity indices. Metrics used to assess robustness include Pearson's correlation coefficient (ρ) and the Average Rank Difference (ARD).

Our findings reveal a non-linear relationship between sample size and the robustness of the sensitivity analysis results. Smaller sample sizes lead to greater variability in SRC values and the ranking of alternatives, whereas larger sample sizes tend to stabilize these sensitivity metrics. We identified that a threshold sample size of 10n provides a balance between computational efficiency and result accuracy when considering the similarity and stability of ρ. However, when evaluating the stability of ARD values across the entire ranking, a sample size of 100n is required, while a sample size of 30n is sufficient to stabilize ARD values when focusing only on the top five ranks. This study highlights the importance of selecting an appropriate sample size for robust sensitivity analysis results. The findings offer practical guidelines for researchers and practitioners to determine optimal sample sizes, ensuring reliable and stable results while managing computational costs effectively.

Parametric analysis of the effect of window blind control on energy consumption of high-rise office buildings in high-density cities

Cong Yu, Wei Pan, Yumin Liang
The University of Hong Kong, Hong Kong S.A.R. (China)

Window blinds serve as effective shading devices, that block incoming sunlight; however, previous studies have generally neglected the shading effect from surrounding buildings when assessing the energy performance of window blinds. This omission may result in an overestimation of the impact of window blinds on building energy consumption, leading to inaccurate energy performance assessment. In addition, research on the impact of various window blind patterns and different community morphologies on building energy consumption remains insufficient. This paper aims to address these issues by examining the joint effect of various window blind control systems and surrounding buildings on building energy consumption through parametric analysis. Four high-rise office buildings in urban Hong Kong with varying window properties were selected for case studies. A novel approach was developed, integrating tools such as DesignBuilder for modelling surrounding buildings using geospatial data from Google Earth Pro, EnergyPlus for simulating the building energy consumption, and JEPlus and Python for automating the parametric models. Three types of internal window blinds with high, medium and low reflectivity and four operation modes (i.e., no shading device, 100, 200, 300 W/m2, and always on) were analysed. Isolated buildings with and without window blinds were also considered, resulting in 64 modelled combinations. The results show significant variation in the impact of window blinds, with a maximum increase of 7.64% in total energy consumption for the whole building compared to buildings without blinds. The study concludes that in high-density cities, window blind control and surrounding buildings should be jointly considered for achieving accurate building energy performance assessment. Methodologically, it provides an innovative approach for coupling various tools to conduct parametric analyses for energy consumption prediction. Theoretically, this study proposes a new perspective for accurately predicting energy consumption by emphasising the necessity of considering the joint effect of window blinds and surrounding buildings.

【DESIGN 02: Automatic Design】

9th December, 10:45am ~ 12:00 pm

Session Chair: Zhe Wang, The Hong Kong University of Science and Technology

Session Chair: Masato Miyata, National Institute for Land and Infrastructure Management

Automatic Design for Subway Station HVAC System Control Flow Chart Based on BIM or 2D Drawings

Jiefan Gu[1], Weixiang Wang[2], Tong Xiao[2], Peng Xu[2], Ruiying Jin[2], Zhangxin Xiong[2]
[1]College of Architecture and Urban Planning, Tongji University, Shanghai, China; [2]School of Mechanical Engineering, Tongji University, Shanghai, China

With the development of urban rail transit construction in China, the demand for subway station design has grown rapidly in a short period of time. The heating, ventilation and air conditioning (HVAC) system control flow charts are crucial in subway station design, which describe the energy efficient operation strategy and control requirements of each HVAC sub-system in detail. Because HVAC systems in subway station are complex and have high requirements for fire and smoke protection, the traditional design process of control flow charts is time-consuming and labor-intensive, and it is easy to miss device information and make mistakes in the control modes due to manual errors. In order to improve the efficiency of HVAC system design in subway stations, this paper proposes a method and develops an application software to design control flow charts automatically for subway stations based on BIM or 2D HVAC system drawings. Firstly, the HVAC system topology is extracted from BIM or 2D drawings. Secondly, a HVAC system control strategy database is constructed based on large language models, which store different strategies in normal control mode, fire mode and energy efficient mode. Finally, the control flow charts are generated automatically based on HVAC system topology and control strategy database. A case study of subway station control flow chart design is shown in this paper. This proposed method can quickly and automatically generate HVAC system flow charts, effectively improve the efficiency and accuracy of the subway station HVAC system design.

Automatic design of HVAC water system pipelines based on multi-agent ant colony algorithm

Junjie LI, Hang Guan, Peng Xu
School of Mechanical Engineering, Tongji University, Shanghai, China

The design process of HVAC water piping systems is typically characterized by its complexity and time-consuming nature. Engineers must balance numerous variables and constraints, such as thermal load, pipe size, pipe accessory selection, and layout configuration. In traditional design processes, engineers rely on experience and simplified models for design decisions, which often fail to fully explore the design space and produce optimal solutions, resulting in hydraulic imbalances and increased costs. This study uses building floor plan information and equipment layout results as inputs, considering factors such as pipe length, the number of accessories, hydraulic balance, and obstacle avoidance, to automatically generate the piping layout for HVAC water systems. Specifically, the escape graph method is used to model the building space. Then, a multi-agent ant colony algorithm is applied to optimize path length and the number of elbows, achieving an obstacle-avoiding HVAC water system piping layout. Based on expert knowledge, a hydraulic calculation model is proposed, including size selection, loop resistance calculation, and a hydraulic balancing model. Finally, the generated water system layouts are quantitatively evaluated based on loop balance. This method is verified within the framework of an automatic

design process and produces satisfactory pipeline layout results while reducing design time and workload.

BIM-BASED AUTOMATIC ARRANGEMENT AND WIRING PROCESSES FOR FIRE ALARM SYSTEMS IN METRO STATIONS

Ruiying Jin[1], Peng Xu[1], Junjie Li[1], Hongxin Wang[1], Jiefan Gu[2], Ting Lin[3], Wei Lyu[3]
[1]School of Mechanical Engineering, Tongji University, Shanghai, China; [2]College of Architecture and Urban Planning, Tongji University, Shanghai, China; [3]Fuzhou Rail Transit Design Institute Co., Fuzhou, China

The automatic fire alarm system (FAS) is an important part of the building intelligence system. It can safeguard people's lives and national property security. During the design process of fire alarm systems in metro stations, designers need to strictly implement the design specifications. Due to the complexity of the fire alarm systems in subway stations, which involve a wide variety and a large number of devices, the traditional process of creating graphic design drawings entails a lot of repetitive work, making it time-consuming and labor-intensive. Therefore, this paper proposes a BIM-based automatic arrangement and wiring process for fire alarm systems in metro stations to solve the problem. Firstly, the building and device information is extracted from the building information model (BIM). Secondly, the arrangement algorithms are classified based on polygonal planes and polygon edges according to the different positions of different types of devices. A set of algorithms such as the ant colony algorithm and Prim algorithm is introduced for the automatic wiring of FAS devices in metro stations, ensuring compliance with the mandatory design requirements for various device types. Finally, the method proposed in this paper has been tested in a real metro building, and the design results have been endorsed by designers. Compared with the traditional design results, using the automatic design process proposed in this paper can improve the design efficiency of the fire alarm systems in metro stations and save construction costs to a certain extent.

A novel method of automated generation and optimization for energy saving 3D building space layout

Peiying Huang[2,3], Pengyuan Shen[1]
[1]Department of Future Human Habitat, Shenzhen International Graduate School, Tsinghua University, China, People's Republic of; [2]China State Construction Hailong Technology Company Limited, Shenzhen, China, People's Republic of; [3]School of Architecture, Harbin Institute of Technology, Shenzhen, China, People's Republic of

Achieving carbon neutrality requires energy-efficient building design. This paper presents a novel framework for the automated generation and optimization of energysaving 3D building space layouts, focusing on the impact of space arrangement within fixed building contours on energy performance. The method utilizes RhinoGrasshopper and custom Python scripts to create diverse layout schemes and employs a multi-objective evolutionary algorithm to optimize energy efficiency while ensuring practical usability. The framework assesses building energy performance using an annual energy use metric, considering heating, cooling, lighting, and equipment loads. It also evaluates the spatial rationality through floor allocation and privacy scores. By creating adaptable 3D grid models projected onto irregular building geometries, the method enhances layout versatility. A case study on a high-rise mixed-use office building in Shenzhen, China, demonstrates the framework's efficacy, achieving up to a 5.5% reduction in annual energy load. The optimization process yielded layout schemes with high spatial rationality, validated by clustering Pareto-optimal solutions. This research offers an automated,

computational approach to optimizing space layouts for energy efficiency, applicable to multi-story buildings.

Window Design Optimization for a Balanced Daylight Environment Based on Parametric Modeling and Genetic Algorithms

Brian Yaputra[1], Ken Takahashi[1], Jia Tian[1], Ryozo Ooka[2]
[1]The University of Tokyo, Japan; [2]Institute of Industrial Science, The University of Tokyo

This research aims to optimize window configurations in buildings with single-sided lighting, focusing on sustainable design practices that enhance daylighting without relying on traditional control devices like blinds and shades. The study addresses the challenges posed by larger windows, which, while increasing daylight penetration, often necessitate mechanisms to manage glare and excessive sunlight, particularly in large, side-lit office spaces.

Previous studies on window optimization have typically concentrated on specific climates or building types, limiting their general applicability. Additionally, these studies often neglect the complex interrelationships between various input variables and essential daylighting metrics beyond mere illuminance, resulting in ambiguities about the effectiveness and accuracy of the optimization processes.

By employing parametric design and building simulation modeling, this study utilizes evolutionary algorithms to determine optimal window geometries that maximize indoor lighting while effectively controlling glare and excessive light levels. This approach also considers diverse environmental impacts and the dynamic nature of daylight, investigating appropriate input variables to enhance the relevance and applicability of the findings.

The results underscore the importance of adapting window designs to specific climates, demonstrating an average improvement of 18.19% in spatial Daylight Autonomy (sDA), while ensuring that values of Annual Sunlight Exposure (ASE) and Spatial Glare Autonomy (sGA) are maintained within acceptable levels. Genetic Algorithms (GA) are highly efficient for optimization, reducing the time required from days or months (as typical with traditional grid search simulations) to approximately 10 hours. This significant reduction in time showcases the potential of GA to streamline the optimization process, providing valuable insights for various climatic conditions and building configurations.

【DIGITAL 01: BIM & Digitalization of Building Practice】

9th December, 10:45am ~ 12:00 pm

Session Chair: Gyuyoung Yoon, Nagoya City University

Session Chair: Hongwen Dou, École de technologie supérieure

A Robust Method for Generating Building Energy Models from Building Information Models or 2D Design Drawings

Yi Zhu[1], Jiefan Gu[2], Peng Xu[1]
[1]School of Mechanical Engineering, Tongji University, Shanghai, China.; [2]College of Architecture and Urban Planning, Tongji University, Shanghai, China

Building energy modeling is time-consuming and labor-intensive, while the structure of building information is also very complex. Geometric problems emerge in the process of transforming building information models (BIM) into building energy models (BEM). For example, geometric information directly extracted from BIM models often contains numerous fragmented geometric surfaces and curves, which significantly increase the complexity and computational cost of the BEM models. To improve the generality of this process and reduce the constraint of input models, this paper proposes a method for generating BEM models from building floor contour information. Firstly, the building floor contour information comes from 3D BIM models or 2D design drawings, and it is exported into XML files. Secondly, complex geometric information such as curved surfaces is simplified. Based on that, a mathematical projection method is used to identify and divide interior and exterior walls by comparing the spacing of walls with the threshold. Then, the comparison result is used to generate computable BEM models with other essential information. In test buildings, this method successfully identifies and divides interior and exterior walls from simplified floor information. It reduces the precision requirement of the original input models, enhances the generality of models, and is applicable for both 2D and 3D input files.

Comparison of the onsite thermal measurement and simulated indoor climate to test building digital twin concept

Yichen Guo, Genku Kayo
Tokyo City University, Japan

Applying building performance simulation in operation has a potential to realize building digital twins. However, there are some factors that cause discrepancies between simulated results and real indoor environment. The factors are for example weather dataset, schedules of equipment operation and occupants' activities,

The article describes the errors of thermal modeling of campus buildings, and analyzed the considerations for applying digital twin concept. With the goal of characterizing room temperature calculation errors, this research examined three aspects: weather data, air temperature, and cooling load of classrooms in campus building located in Yokohama, Japan. The calculated average air temperature of the south classroom is 0.51°C higher than that of the north classroom. The simulated value is 1.16°C higher in average than the measured value in case of the north-side classroom. Because the situation of solar irradiation in weather data is not the same as actual outdoor condition, the difference of calculated and simulated values of the south-side classroom is larger than those of the north-side classroom,

Since the situation and operation of buildings are totally diverse, the application of BPS for digital twin concept has a lot of consideration. The fundamental study shown in the article provided the opportunity to recognize the gaps in the simulated and measured results. To apply digital twin concept in practice, improvement of weather data application is one of the essentials.

Demonstration of an AI-empowered and MR-assisted Platform for Indoor Environment Management

JING ZHANG[1], Tianyou MA[1], Fu XIAO[1,2]
[1]Department of Building Environment and Energy Engineering, The Hong Kong Polytechnic University, Hong Kong SAR, China; [2]Research Institute for Smart Energy, The Hong Kong Polytechnic University, Hong Kong SAR, China

The indoor environment is essential for human comfort and well-being. The widespread use of the well-mixing assumption in managing central air conditioning systems, coupled with the lack of measurement points in the occupant zone, presents a significant challenge in accurately assessing thermal comfort, particularly in large spaces. Currently, the control of indoor environment heavily relies on manual experience, presenting significant potential for improvement in both thermal comfort and energy efficiency. To address this issue, this study implemented IoT sensors in the occupant zone of a typical office building floor to collect indoor temperature data. A Graph Neural Network-Recurrent Neural Network (GNN-RNN) model was developed to predict the temperature throughout space. The effectiveness of the GNN-RNN model-based control strategy was then tested in the office building, resulting in a significant improvement in thermal comfort. Furthermore, a Mixed Reality (MR)-assisted platform was developed to provide enhanced indoor environment data visualization and an interactive interface for on-site operators. This research demonstrates the potential of integrating IoT, AI, and MR technologies to optimize indoor environment management, offering promising implications for enhancing occupant comfort and energy efficiency in large indoor spaces.

Using An Open-source Software Stack to Visualize Building Automation System Data in 3D

Kian Wee Chen[1,3], Makoto Nishizawa[2], Ippei Izuhara[1,2,3], Forrest Meggers[3,4]
[1]Global Environmental Technologies Inc., United States of America; [2]Sanken Setsubi Kogyo Co., Ltd, Japan; [3]Andlinger Center for Energy and the Environment, Princeton University, United States of America; [4]School of Architecture, Princeton University, United States of America

This research aims to make Building Automation System (BAS) data more accessible to building occupants by better visualizing them in a 3D environment. Current 3D solutions require a high-level of expertise, customization and integration that prohibit adoption, especially for small and medium scale projects. We developed a streamlined workflow based on an open-source software stack and open data standards. As a result, the solution, a web-based application, can be readily customized and adopted in projects with very low monetary cost. In addition, the use of existing open technologies allows the solution to be readily extensible and maintainable by most software developers. The web-based application is currently live streaming BAS data from the BCA-Sanken research space in 3D (https://databca.globalenvtech.com/csviewer) and in graph visualizations (https://databca.globalenvtech.com/grafana). The 3D dashboard is made available to the public for visualizing data from 6am to the current time while the password protected graph dashboard allows the user to view the entire trend of the BAS data hosted on the time-series database. The online web platform has been very useful for the sharing of BAS data among collaborators. Researchers from different institutions are able to readily push and pull data from the platform using an open standard API and effectively visualize

them either through graphs or a 3D environment. Further work will be required to streamline the processing of 3D Building Information Model (BIM) data, test the scalability of the solution and extend the capabilities of the web application beyond visualization to include more advanced analytics.

【FUTURE 01: Urban-scale Simulation】

9th December, 10:45am ~ 12:00 pm

Session Chair: Jihui Yuan, Osaka Metropolitan University

Session Chair: Yunran Min, Jimei University

Effects of District-scale Adaptation Measures on Future Microclimates under Different Climate Change Scenarios

Junya Yamasaki[1], Yubei Liu[1], Satoru Iizuka[1], Takahiro Yoshida[2], Ryoichi Nitanai[2], Rikutaro Manabe[2], Akito Murayama[2]
[1]Nagoya University, Japan; [2]The University of Tokyo, Japan

When considering heat-related measures at the district scale, it is essential to adopt a long-term perspective that incorporates the potential impacts of climate change. Recent studies have been conducted to simulate district-scale future microclimates and to evaluate the effects of introducing heat-related measures under such conditions. However, those studies focused mainly on case settings of weather conditions and measures, and the building stocks often remained essentially fixed from the base year (the present status). To apply simulation techniques (Computational Fluid Dynamics: CFD) to planning practices, it is necessary to create scenarios incorporating both urban forms and weather conditions based on expected future development trends, and to identify optimal heat-related measures under each scenario. Thus, in this study, we first conducted a future microclimate simulation that reflects both changes in building stocks and broader-scale future temperature rises based on the frameworks of Shared Socioeconomic Pathways (SSP) and Representative Concentration Pathways (RCP). Second, we quantitatively evaluated the effects of changing the ground and building surface materials as adaptation measures for each scenario. We selected an urban center district of the Nagoya metropolitan area in Japan as a case study site, and simulated the daytime microclimate on a summer day in the 2090s. Future scenarios were selected: SSP1-2.6 as the sustainability scenario, SSP2-4.5 as the middle of the road scenario, and SSP5-8.5 as the fossil-fueled development scenario. The results suggest that broader-scale future temperature rises directly affect district-scale (local) air temperatures, while changes in building stocks and heat-related measures affect mean radiant temperatures (MRT), mitigating the effects on heat-related risks. These findings will contribute to the selection of effective district-scale adaptation measures under each scenario to address the impacts of future climate change in urban areas.

Thermal comfort interventions and urban building energy modeling for informal settlements - A study in Bihar, India

Yu Qian Ang, Sparsh .
National University of Singapore

Informal settlements and slums are home to over 1 billion people worldwide, with an estimated 30-50% of the urban population in developing countries residing in these areas. Many living in these settlements risk exposure to extreme heat and thermal discomfort. Despite the global scale of this issue, the living conditions and thermal comfort of these settlements remain understudied. This research addresses this gap by applying low-cost interventions and urban building energy modeling (UBEM) to an informal settlement in Bihar, India.
The study began by collecting building characteristics and occupant persona data to understand the

settlements' (and their inhabitants') characteristics. Low-cost interventions were then identified and pilot-tested in the settlement. Subsequently, an urban building energy model was developed to simulate the settlements' thermal performance. For the economically disadvantaged residents of informal settlements, thermal comfort and health improvements take precedence over energy efficiency – the interventions thus focus on passive design strategies that can be implemented cheaply and with locally available resources.
This study also demonstrates the potential of UBEM as a tool for understanding and improving the living conditions in informal settlements. By prioritizing the thermal comfort and health of occupants, the proposed interventions can significantly enhance the quality of life for the often-overlooked residents of these communities. The findings of this research can inform policymakers, urban planners, and NGOs in developing targeted strategies to upgrade informal settlements, contributing to the United Nations' Sustainable Development Goals.

Urban-Scale Simulation of Rooftop Photovoltaic Panels to Mitigate Extreme Heat in Coastal Metropolis Tokyo

DUN ZHU[1], RYOZO OOKA[2]
[1]School of Engineering, the University of Tokyo; [2]Institute of Industrial Science, the University of Tokyo

Rooftop mitigation strategies, such as green roofs and rooftop photovoltaic (PV) panels, have potential for reducing ambient temperature during hot weather and reducing carbon emissions. Therefore, predicting their impact on the urban thermal environment at an urban scale is crucial to address increasingly frequent and severe extreme heat events caused by global warming. However, accurately quantifying urban form in mesoscale meteorological models remains a challenge. In this study, gridded urban canopy parameters were built for Tokyo, a coastal metropolis, and applied to the Weather Research and Forecasting model coupled with a multi-layer urban canopy model. Sixteen hot days were chosen to analyze the air temperature reduction potential from rooftop PV panels, and the convective heat transfer coefficient parameterization scheme has been adapted for coastal cities based on the Monin–Obukhov similarity theory. The results indicated that PV panels with 50% coverage achieved the most significant reductions in regional average pedestrian-level air temperatures at 2 PM, with reductions of 0.10 °C. The daily peak of regional maximum cooling effects for were also observed around 2 PM, reaching 0.25 °C. The regional maximum air temperature reduction of PV panels was observed in the northwest hinterland horizontally and 8 m vertically, indicating a combined effect of sea breeze advection and urban form. Furthermore, it is shown that PV conversion efficiency significantly influences the air temperature reduction capability of PV panels, and a 10% efficiency could be the threshold for mitigating or exacerbating high temperatures in Tokyo when installed on an urban scale.

Urban solar energy potential in Singapore: a physics-based simulation and deep learning approach

Yifei Wu[1], Tian Yi Chen[1,2], Yu Qian Ang[1]
[1]National University of Singapore; [2]Solar Energy Research Institute of Singapore

As dense urban environments grapple with the transition to renewable energy, solar energy – specifically rooftop and façade-integrated solar photovoltaics (PV) – represents the predominant feasible renewable energy source for the built environment. This study evaluates the viability of solar energy in high-density urban settings, using Singapore as a case study. The research analyzed annual PV potential and the return on investment for over 10,000 residential buildings (public housing), focusing on rooftop and façade PV. Our methodology combined open-source geographical information system layers with

energy use reports. The physics-based simulation results were subsequently trained with medium-resolution satellite imagery on a conditional generative adversarial network to provide rapid solar potential assessment, offering quick design feedback at the early stage. Results indicate that solar energy deployment on rooftops can supplement up to 20.21% of the energy use in residential buildings, while building-integrated photovoltaics (BIPV) on façades can contribute up to 8.61%. However, while rooftop installations demonstrate cost-effectiveness, façade BIPV systems may not be economically viable in dense urban environments. The study can provide valuable insights for policymakers and urban planners, facilitating evidence-based decisions on integrating PV into the residential built environment of dense cities.

People in Cities: Combining subjective occupant feedback with urban-scale data to support indoor and outdoor thermal comfort

Martin Mosteiro-Romero[1], Yujin Park[2], Clayton Miller[3]
[1]Department of Architectural Engineering and Technology, TU Delft, Netherlands; [2]Department of Urban Planning and Real Estate, Chung-Ang University, Seoul, South Korea; [3]Department of the Built Environment, National University of Singapore, Singapore

The increasing availability of urban-scale, open-access datasets can support decision-making in urban planning, in particular in relation to climate resilience and climate change mitigation. Such data-driven initiatives however often neglect the central role of urban dwellers, whose activities create the demand for energy and mobility in urban areas. This is due in large part due to the difficulty of data collection at this scale, along with privacy concerns arising from any such data collection effort. The use of wearable technologies for self-reported comfort feedback from urban dwellers provides a promising opportunity for citizens to actively participate in the adaptation of urban areas to better support outdoor comfort and climate resilience.

In this work, subjective feedback data from 22 participants in a longitudinal test in Seoul, South Korea was collected through a smartwatch application. Participants were required to wear a smartwatch for 4–6 weeks, during which time their location as well as environmental and physiological data were collected. Participants were also requested to complete hourly micro-surveys, in which they were asked about their activities, location, thermal preference, clothing level, comfort adaptations, and mood. This information was complemented by an urban scale dataset comprising building geometries and data from 1000+ weather stations over the same period.

This cross-scale dataset was then used to investigate the relationship between urban form and environmental parameters with occupants' survey responses. The relationship between indoor comfort and environmental parameters in the case study is discussed, with recommendations for further research into this topic. The use of machine learning to leverage the combination of spatial, temporal, and subjective preference data to predict occupants' outdoor comfort as a function of their urban environment is also explored.

【HUMAN 01: Occupant Behavior】

9th December, 10:45am ~ 12:00 pm

Session Chair: Cheol Soo Park, Seoul National University

Session Chair: Xuyuan Kang, Tsinghua University

Questionnaire-based Analysis of Psychological Characteristics, Office Environment, and Thermal Adaptation-Related Behavior of Office Occupants in Japan

Qingyi He[1], Daisuke Sumiyoshi[2]
[1]Graduate School of Human-Environment Studies, Kyushu University, Japan; [2]Faculty of Human-Environment Studies, Kyushu University, Japan

In Japan, where commercial and public sectors account for 54% of energy consumption, this study explores the relationship between office occupants' environmental psychology and their thermal adaptation behaviors. Utilizing the Theory of Planned Behavior, data were collected through a questionnaire that analyzed psychological traits, environmental perceptions, and adaptation actions. Statistical methods such as t-tests and ANOVA showed that higher environmental awareness among office occupants leads to increased energy-saving behaviors. The study also highlights how characteristics such as gender and age influence the expression of temperature preferences and behaviors. This finding supports the need for tailored educational programs and policy changes to enhance building energy efficiency.

Research on indoor thermal environment control based on occupant behavior intention prediction

Wanyue Chen[1], Yan Ding[1,2], Shengze Lu[1], Ler Yee How[1], Tiantian Li[1]
[1]School of Environmental Science and Engineering, Tianjin University, China; [2]Tianjin Key Laboratory of Built Environment and Energy Application, Tianjin University, China

The interaction between occupants and buildings is key to the intelligent operation and control of occupant-centric air conditioning systems. Occupants' thermal states, influenced by indoor environmental changes, are inherently dynamic, yet traditional recognition methods relying on a single parameter often fail to capture the complexity of their true thermal needs. To address this limitation, three distinct heat stress mechanisms - the heat exchange system, the cardiovascular system, and the brain nervous system, are integrated into a comprehensive model for thermal sensation prediction in this study. By using a Copula joint function, the likelihood of thermal regulation behavior is simulated based on the dynamic interaction of integrated thermal sensation, environment indexes and time factors, which serves as a foundation for a Q-learning reinforcement learning model designed to precisely control indoor temperature. The results indicate that the integrated thermal sensation model provides a more accurate reflection of occupants' thermal states compared to traditional stepwise models. Combining integrated thermal sensation with environmental and temporal variables can significantly enhance the accuracy of behavioral intention simulations. Under both gradual and abrupt changes in indoor temperature, the control strategy that considers behavior intention is more effective at reducing cumulative thermal discomfort and its duration.

The impact of the built environment on changing lifestyles and physical activities during the COVID-19 lockdown period in London

DI YANG[1], Hao Yang[2]
[1]Newcastle University, United Kingdom; [2]Nankai University

The properties of the built environment (BE) during non-pandemic periods effectively promote people's physical activity (PA) which improves health outcomes and brings economic benefits. However, the role of BE features in changing PA during the COVID-19 pandemic, and whether favourable BE features can mitigate the decrease in PA caused by restrictions, remains unclear. There is currently no scientific evidence to explain how and why people's PA levels and lifestyles were affected by the UK's lockdown policies and changes in the BE. This blank space may limit opportunities to slow the decline in PA caused by current and future pandemics. In this study, qualitative data were analysed using system dynamics and the construction of models (causal cycle diagram, causal chain, etc.) to establish the causal relationship between the BE and PA. This served to elucidate the impact of the BE on residents' lifestyles and PA during UK lockdown and its regulating effect. The results showed that residential density, a feature of the BE during the epidemic, affected the spread of the virus and the level of PA in residents. Another feature was proximity to the destination which also led to a reduction in PA. Conversely, land-use patterns and the presence of green landscapes and parks effectively increased the level of PA in residents. To reduce the risk of transmission of the virus, it is necessary to create more accessible green parks, build low-density communities, ensure the perceived safety of residents and make communities more resilient to crises and epidemics. Lack of PA harms the body; thus, strategies need to be developed to promote lifestyle changes that maintain acceptable levels of PA and ensure lasting mental and physical health.

Proposal for a behavior change to significantly reduce air-conditioning energy consumption by the combination of short stay in a limited cooling space and cooling clothing in working spaces

Satoru Iizuka, Teruyuki Saito, Yasuhiko Nishizawa, Mariko Yamasaki, Junya Yamasaki
Nagoya University, Japan

In policies and actions focused on carbon neutrality and decarbonization, the first thing to deal with is to pursue energy-saving strategies. As part of the strategies, this study proposes a behavior change aimed at significantly reducing the air-conditioning energy consumptions during summer seasons in office buildings and educational facilities. The aim is to minimize, and ideally remove, the air-conditioning (cooling) energy consumptions used in working spaces by staying in a limited cooling space for a short time immediately after entering building or facility to cool down in advance (for pre-cooling), and then wearing cooling clothing in working spaces. Limited cooling space and cooling clothing themselves are not new technologies; however, the behavior change through their combination is a new concept that has never been seen before. In this study, we investigate the individual and combined effects of the limited cooling space and cooling clothing through a series of subject experiments, and based on the experimental results, the strategies for applying the proposed behavior change are discussed.

Human-centric Air Conditioning System with Seat Changes: Control Logic Combining Seat Change Recommendations and Air Conditioning Control

Yohsuke Kamiya[1], Ruizi Zhang[2], Hiroaki Kanayama[2], Daisuke Sato[2], Nobuki Matsui[2], Keiichiro Taniguchi[1], Yasunori Akashi[1]
[1]the University of Tokyo, Japan; [2]Daikin Industries, Ltd., Japan

In recent years, many studies have focused on developing air conditioning systems capable of assessing individual thermal sensations and adapting to varying thermal preferences. In addition, with the spread of hot-desking and activity-based working (ABW) in office spaces, workstyles in which seating is selected and moved based on individual preferences have received similar attention. Based on these backgrounds, this research aims to develop a system for matching thermal environments that accommodate individual differences in thermal preferences through seat recommendations and air conditioning control. The goal is to identify the control logic that best operates this system. We first evaluated the impact of seat changes on satisfaction through preliminary experiments. Next, we modeled the data from each subject and the room's behavior obtained from these experiments and constructed a multi-agent simulation. By evaluating multiple control logics within this simulation, we aimed to clarify which control logic is most appropriate.

【SYSTEM 01: Smart Building Applications】

9th December, 10:45am ~ 12:00 pm

Session Chair: Yiqun Pan, Carnegie Mellon University

Session Chair: Hideki TANAKA, Nagoya University

Annual simulation on window-opening control for improving thermal comfort in naturally ventilated buildings installed phase change materials under hot and humid conditions

Haruka Kitagawa[1], Takashi Asawa[2], Yukari Hirayama[3]
[1]Institute of Technology, Shimizu Corporation, Japan; [2]School of Environment and Society, Tokyo Institute of Technology, Japan; [3]School of Architecture, Kogakuin University, Japan

A combination of multiple passive cooling methods was suggested to improve the cooling effect in previous studies because the single passive cooling method alone tends to be insufficient to achieve thermal comfort during daytime in hot and humid climates. This study aims to determine the optimum window-opening control that maximizes annual thermal comfort using a combination of ventilative cooling (i.e., night and comfort ventilation) and the thermal storage effect of phase change materials (PCMs). To evaluate the effect of this combination on annual thermal comfort, an EnergyPlusbased thermal energy simulation coupled with an airflow network model was constructed. Additionally, a linear regression method was developed using CFD to calculate the indoor air velocities for assessing thermal comfort based on the airflow rate. The constructed coupled simulation model was validated by comparing it with the results of a field measurement using a full-scale experimental building in Indonesia. The results showed that the root-means-square errors of the air velocity and temperature at the center of the target building was 0.2 m/s and 0.2–0.5 ℃, respectively. The combination of the thermal storage effect of the PCMs and the horizontal pivot window which is a preferable window system for ventilative cooling with optimum windowopening control increased the thermal comfort period based on SET* up to 82.4% throughout the year. In the morning, the thermal storage effect of PCMs using night ventilation extended the thermal comfort period. As the outdoor air temperature increased, the outdoor wind speed tended to become higher. Therefore, the comfort ventilation compensated for the increased air temperature. Given the effect of room temperature and air velocity on thermal comfort, opening the windows when the indoor temperature is more than 27 ℃ can maximize the annual thermal comfort in the hot and humid climates.

Integrating AI Text-to-Image to enhance window view quality

Thanyalak Srisamranrungruang[1], Kyosuke Hiyama[2]
[1]The Organization for The Strategic Coordination of Research and Intellectual Properties, Meiji University, Japan; [2]School of Science and Technology, Meiji University, Japan

Artificial intelligence (AI) is used in a wide range of applications today. Text-To-Image is an AI technology that is gradually favored in Arts, Advertising, Design, Games, Education, and Research. This technique aids humans in creating mental imagery into tangible crafted images. Window views are a significant key in architecture that impacts the well-being of occupants. Even though window views are important and beneficial, but design guidelines for window view quality assessments are limited. This study aims to apply AI Text-to-Image to create window views for occupants in buildings based on scientific concepts of window view quality. Begin this study by interpreting the window view quality criteria and composing text to create a visual narrative. The following stage of this study is to validate

created AI views by comparing elements in the images with a window view quality scheme. This study proposes a semantic segmentation algorithm to analyze pixels of each element in a scene based on a window view quality scheme. Conclusions, this study presents a new way of creating window views for occupants in buildings by deploying an AI Text-to-Image tool that can enhance the creativity of architectural design on window views. Additionally, this study suggests keyword recommendations to define scenes of window views. Comparisons between a window view quality scheme and generated AI views by using semantic segmentation are presented.

Enhancing Building Services Management Systems with AI and Semantic Modeling: A Case Study on Improving System Efficiency through an AI-based Knowledge Library

Ya Bing Hou[1], Calvin Kin Fung Leung[1], Patrick Pok Man So[1], Arthur Chi Chuen Chan[2], Ridwan Raheem[2]
[1]Electrical and Mechanical Services Department, Hong Kong S.A.R. (China); [2]SagaDigits Limited

This study explores the integration of Artificial Intelligence (AI) and semantic modeling to enhance the operational efficiency of smart building management systems (BMS). We present an AI-driven knowledge base utilizing a multi-agent architecture and large language model (LLM) to optimize building services, streamline management tasks, and implement energy-saving strategies. The multi-agent framework enables autonomous task management and allows natural language interactions via a chatbot interface for data access and analysis. The system further automates the creation and deployment of machine learning models, improving system scalability by rapidly replicating models across multiple buildings. Key outcomes include enhanced scalability and optimized energy consumption, demonstrating the system's ability to increase the efficiency. A case study illustrates the system's practical application, showcasing substantially reduction in implementation time with only a slight decrease in accuracy, leading to considerable improvements in energy management and operational efficiency within smart buildings.

Model-Based Optimal Control for Multizone VAV Systems Considering Indoor Temperature, CO2, and Pressure Regulation

Shanrui Shi, Shohei MIYATA, Yasunori AKASHI
Department of Architecture, Graduate School of Engineering, The University of Tokyo

Conventional model-based optimal control strategies for multizone variable air volume systems often rely on optimizing the setpoints and neglecting the return air side, leading to unbalanced room pressure and air leakage. To address this issue, this study proposes a model-based optimal control strategy to concurrently regulate indoor air temperature, CO2 concentration, and room pressure while minimizing energy consumption. The proposed strategy directly optimizes fan frequencies and damper openings using a datadriven duct network model. Simulation results show that the proposed strategy maintains indoor air temperature and CO2 concentration and reduces air leakage without increasing energy consumption.

A Plug-and-Play Workflow for Data-Driven AFDD Application Development Using Brick Schema

Mengtian Huang, Shohei Miyata, Keiichiro Taniguchi, Yasunori Akashi
The University of Tokyo, Tokyo, Japan

HVAC (Heating, Ventilation, and Air Conditioning) accounts for around 30-50% of total energy consumption during the operational phase of buildings, addressing the need for efficient energy management. AFDD (Automated Fault Detection and Diagnosis) helps identify faults that impact system performance. Data-driven approaches with machine learning techniques offer higher accuracy and reduce dependence on skilled operators' knowledge, but face challenges like diverse system structures and high implementation costs.

To address these challenges, our research proposes a unique plug-and-play workflow for generic AFDD application development using Brick Schema. In the workflow, component-level simulation model is generated to produce fault data as training data for NNs (Neural Networks), and HPO (Hyperparameter Optimization) strategy is applied to automize the training process. All These steps are autonomously conducted by retrieving equipment information from the Brick model in order to adapt to the context of the subject building.

We evaluated this workflow through a case study of two HVAC systems: a factory's primary circuit with chillers and cooling towers, and an experimental residence's secondary circuit with an AHU. The study highlights the benefits of the use of metadata models in application development and outlines future challenges.

【SYSTEM 02: HVAC system】

9th December, 10:45am ~ 12:00 pm

Session Chair: Sayaka Kindaichi, Hiroshima University

Session Chair: Ruijun Chen, The University of Hong Hong

Research on AC cooling consumption of residential community under the perspective of sufficiency

Wenyi Wei[1], Xin Zhou[1], Yi Wu[2], Jinjing Zhao[1], Xiaohan Shen[1], Da Yan[2]
[1]School of Architecture, Southeast University, Nanjing, Jiangsu Province 210096, China; [2]School of Architecture, Tsinghua University, Beijing 100084, China

In order to reduce the cooling consumption of air conditioning (AC) systems in residential buildings, the concept of sufficiency has received increasing attention. However, when analyzing the cooling consumption of AC systems in residential buildings, existing studies often lack a comprehensive analysis of the balance between supply and demand in terms of time, space, and setting temperature, resulting in wasted cooling consumption. Therefore, this study investigates the cooling consumption of AC in residential buildings from the perspective of sufficiency. First, this study establishes a cooling consumption analysis model for a typical residential community, and designs four AC supply modes, which represent different levels of sufficiency (LoS) from the dimensions of space, time, and setting temperature. Then, this study quantitatively analyzes the differences in AC cooling consumption of residential community under different supply modes. Meanwhile, this study explored the sensitivity of different typical populations to different LoS. And the impact of introducing the sufficiency perspective on the AC cooling consumption of residential community under the changing needs of the population is further discussed. The results show that AC supply modes with different LoS can cause a maximum of 22.63 kWh/m2 difference in district cooling consumption. Among them, there is a significant difference in the sensitivity of AC cooling consumption of different typical populations to supply modes. With the introduction of the concept of sufficiency, through effective behavioral guidance and appropriate matching of AC supply modes, up to 50% increase in cooling consumption can be avoided.

Effectiveness of air leakage control measures for doors open while air conditioner is running in retail stores

Atsuki TANAKA, Sihwan LEE
Nagoya University, Japan

While an air conditioner is running, leaving doors open significantly reduces its operational efficiency and undermines its ability to maintain a comfortable indoor temperature. Despite this, many merchants leave their doors open to attract customers and increase sales. This study aims to clarify the mechanism of energy loss due to open doors during air conditioner operation and to propose effective energy-saving measures. To achieve this, we conducted observations on a major shopping street in Japan during the cooling season. The results show that 75% of the stores on this street operated with their doors open. Additionally, we defined a standard model based on measurements of store and door sizes, as well as indoor temperatures. Using this model, we evaluated the effectiveness of various measures to control air leakage.
In particular, the study revealed the following findings regarding the installation of air curtains: under constant blowing velocity air curtain, the thermal separation efficiency may decrease to a negative

value when the temperature difference between the indoor and outdoor is small. This implies that the use of an air curtain could sometimes increase the air leakage. However, by adjusting the airflow speed based on the temperature difference, the heat-blocking efficiency can be maintained at a high level, approximately 71%.

Investigation of Simplified Whole-House Air Conditioning System in Reinforced Concrete Housing by using CFD

Yuki Muromachi[1], Kozo Takase[1], Masayuki Mae[2]
[1]Tokyo University of Science, Japan; [2]The University of Tokyo, Japan

In recent years, as the insulation performance of collective housings in Japan has continuously improved, there is a growing demand for air conditioning systems that can efficiently handle small thermal loads. In this report, the authors propose the air conditioning and ventilation system capable of achieving comfortable thermal environment for an entire housing with a single wall-mounted air conditioner, targeting the standard mid-floor, middle unit in the insulated reinforced concrete apartment building.
This new air conditioning system consists of a single wall-mounted air conditioner, a ceiling suction chamber, and duct fans with natural air supply and mechanical ventilation. The air discharged from the air conditioner is drawn into the ceiling intake and then distributed to each room by the duct fans. The authors analyzed the optimal fan airflow and vent placement for comfort using steady-state CFD analysis.
As a result, when the supply airflow rate of the fans was increased to 160 m³/h and 200 m³/h in the individual rooms, the room temperature throughout the living space remained mostly above 20°C during heating and mostly below 26°C during cooling. The air velocity throughout the living space stayed within 0.3 m/s. Additionally, when the air supply vent was installed at a height of 1.8 meters, close to the air conditioner, there was little impact on the thermal environment during cooling, but during heating, it significantly reduced cold drafts near the floor by the windows.
In conclusion, it was confirmed that this air conditioning system can achieve a comfortable thermal environment in the standard mid-floor, middle unit of the insulated reinforced concrete apartment building.

Optimizing life cycle performance for an office building in cold climates

Ruijun Chen[1], Yukai Zou[2]
[1]Faculty of Architecture, The University of Hong Kong, Hong Kong Island, Hong Kong Special Administrative Region; [2]School of Architecture and Urban Planning, Guangzhou University, Guangzhou, Guangdong, China

To tackle the gap in considering whole life cycle impacts in current building performance research, this study introduces a resilient design strategy aimed at enhancing life cycle building performance. An ensemble learning model effectively predicts life cycle carbon emissions (LCCE), life cycle costs (LCC), and indoor discomfort hours (IDH). The Two-Archive Evolutionary Algorithm for Constrained Multi-Objective Optimization (C-TAEA) proves highly effective in converging to optimal solutions. Through multi-criteria decision-making methods and adjusting performance weights, the VIKOR method identifies the best resilient design scheme from the Pareto data set. It leads to significant reductions in LCCE, LCC, and IDH. For an office building in a cold region, this approach results in a 56.4% reduction in LCCE, 22.3% in LCC, and 32.2% in IDH. This research offers a comprehensive framework for improving life cycle building performance and supports better decision-making for resilient design.

Monday, 9th December, 1:30pm ~ 2:45pm

【DESIGN 03: Weather and Climate】

9th December, 1:30pm ~ 2:45pm

Session Chair: EIKICHI ONO, Kajima Technical Research Institute

Session Chair: Jia Du, Dalian University of Technology

Development of Future Weather Data Using the Quantile Mapping Technique and its Application in Japan

Yusuke Arima[1], Akihito Ozaki[1], Yuko Kuma[2], Hajime Iseda[3], Gyo Abe[1]
[1]Kyushu University, Japan; [2]Kyushu Sangyo University, Japan; [3]Takenaka Corporation, Japan

As climate change is progressing, the need for adaptation and mitigation measures has become increasingly urgent. Access to future weather data for building simulations is crucial to designing environmentally appropriate buildings under future climatic conditions. Various methods exist for creating future weather data using downscaling techniques such as dynamical downscaling and stochastic weather generators. The most popular method is morphing, which is used to create almost half of the existing future weather data. In the morphing method, future weather data are generated by applying statistical manipulations to current typical meteorological year data using climate change information predicted using global climate models (GCMs). However, this method introduces biases due to mathematical operations because it uses only constant monthly change factors that represent climatic change, indicating that there is room for improvement in this creation method. In this study, we developed a new method for generating future weather data using a technique called quantile mapping. Quantile mapping was originally a method for bias correction of climate model outputs. In our approach, this technique is applied to the creation of future weather data. The quantile mapping-based method is expected to reduce the biases caused by mathematical operations because it considers daily-level change factors and reflects various types of future information predicted using GCMs. We compared the characteristics of future weather data created using the proposed method with the data obtained by morphing. Our findings confirmed that the proposed method can reduce biases in the data transformation process. Additionally, using the developed future weather data, we analyzed trends in future changes in heating and cooling loads and the climatic potential for natural ventilation

Local urban weather data generation based on atmospheric reanalysis data to support building energy design in Singapore

Guanli Feng[1], Xing Zheng[1,2], Naika Meili[2], Shuyang Li[2,3], Martín Mosteiro-Romero[4], Zhen Han[5], Lei Xu[2,6], Dengkai Chi[2], Rudi Stouffs[2,3]
[1]Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong S.A.R. (China); [2]Future Cities Laboratory Global, Singapore-ETH centre, Singapore; [3]Department of Architecture, National University of Singapore, Singapore; [4]Department of Architectural Engineering and Technology, TU Delft, Netherlands; [5]School of Architecture, Tianjin University, China; [6]Department of Architecture, University of Cambridge, UK

Building energy modeling (BEM) is essential for predicting energy use and improving thermal performance in buildings. Traditionally, weather data for BEM comes from built-in tool datasets. Additionally,

global atmospheric reanalysis datasets like ERA5, have been used in recent years for BEM. However, the spatial resolution of global atmospheric reanalysis datasets is generally coarse relative to cities, limiting their accuracy in capturing local urban climate effects. Adopting ERA5 as the forcing data, this study examines the use of two urban land surface models, Urban Tethys-Chloris (UT&C) and Urban Weather Generator (UWG), to generate localized weather data for Singapore. The generated local weather data are compared with the data from an on-campus weather station and other weather datasets. Subsequently, these weather datasets are employed as input for an educational building's energy model that has been validated with energy meter data. The results demonstrate a better agreement between the generated local weather data and locally measured data, compared to the original ERA5 data and typical meteorological year weather data. This leads to an improved accuracy in building energy prediction. By leveraging the global availability of atmospheric reanalysis datasets, this framework for generating local weather data can serve as a universally applicable approach to support building energy design in tropical cities.

Stochastic weather data generation method based on simultaneous occurrence of multiple elements

Zhichao Jiao[1], Jihui Yuan[1], Craig Farnham[1], Da Yan[2], Kazuo Emura[1]
[1]Osaka Metropolitan University, Japan; [2]Tsinghua University, China

Stochastic weather generation methods are widely employed to evaluate weather uncertainty and the implications of future climate change on building heat loads. However, the previous studies usually do not adequately consider the simultaneous occurrence of multiple weather elements, which can compromise the authenticity of the produced weather data and the findings of energy consumption evaluation. To address this issue, this study aims to propose a method for generating hourly meteorological data for building simulation, based on the dependencies between multiple weather elements (air temperature, solar radiation, and absolute humidity). The method used in this study can be divided into two steps: (1) modeling multivariate time series of these three elements at 12:00 for TMY based on the S-vine (stationary vine) copula model and then 365 three-element data were generated as the parameter for each day of the generation year at 12:00, and (2) expanding the generated daily series data at 12:00 for each day to 24 hours based on the transition probability matrix for each element. By generating 30 years of stochastic data and comparing them with the original data, the results show that the air temperature and solar radiation have basically maintained their original distributional characteristics, except for a small difference in the kurtosis of absolute humidity.

Interactive Urban Heat Island Assessment: Dynamic Data Fusion in Digital Twins

Joie Lim[1], Marcel Ignatius[1], Ben Gottkehaskamp[2], Nyuk Hien Wong[1]
[1]Department of Built Environment, National University of Singapore, Singapore.; [2]Chair of Building Technology and Climate Responsive Design, TUM School of Engineering and Design, Technical University of Munich, Germany.

Studies have developed processes and standards to combat the technical difficulties of integrating heterogeneous data sources into unified or interoperable systems for use in Urban Digital Twins. However, while there are impressive implementations that use the data for simulations and studies, many solutions result in static ways to display and interact with information, especially out of the box.
This research explores the combination of data from different sources together with an interactive user interface, such that sensor data and simulation findings can be conveyed more effectively to decision makers and the public. It focuses on microclimate and thermal comfort studies in the context of

assessing Urban Heat Islands, offering new use case scenarios that could be implemented in Urban Digital Twins.

As part of an ongoing campus wide microclimate assessment, through the Baselining, Evaluating, Action, and Monitoring (BEAM) initiative, weather stations, thermal cameras, and meteorological towers have been installed. To complement this, street view images, smartwatch responses, indoor measurements and building energy simulations have also been collected. These are combined into several interactive views. One such view displays the thermal walk, where a combination of 360-degree street view imagery, mobile weather station data and smartwatch responses provide an understanding of how changing urban morphological features in the surrounding area affect measured and perceived thermal conditions. Other views display weather station and thermal camera data. The combination of surface temperatures captured by thermal cameras with information like nearby temperatures, wind speeds, and indoor measurements provide an understanding of the impact of building surface treatments on thermal conditions both inside and outside the building across time.
These interactive views, with combinations of data in different forms, provide the context necessary to understand the links between the data presented, and help communicate factors impacting Urban Heat Islands and their mitigation strategies.

Indoor Thermal Environment and the Effectiveness of Central Air-Conditioning in a Typical Japanese House under Future Climate

Mai Kawamura[1], Akihito Ozaki[1], Yusuke Arima[1], Yuko Kuma[2], Gyo Abe[1], Ryuto Isoya[1]
[1]Kyushu University, Japan; [2]Kyushu Sangyo University, Japan

Alongside the recent progress in climate change, gradual changes to the thermal environment of buildings have also been observed. To design a more comfortable and energy-efficient building environment, it is necessary to appropriately evaluate thermal and energy performance under future climate conditions. This study evaluated the indoor thermal environment considering climate change by simulating the housing thermal environment using future weather data. For the simulation, we used THERB for HAM, a developed thermal simulation software. To consider the impact of climate change, we used future weather data on the climatic information predicted by Global Climate Models from CMIP6. We also considered the gradual future development of building thermal performance, in accordance with Japanese design regulations. Our analysis results indicated that, owing to climate change, the cooling load will increase, and the heating load will decrease. In addition, even if the building thermal performance improve, the latent heat load does not decrease so dehumidification will become a more important issue in a future climate context.

Furthermore, we evaluated the effectiveness of the central air conditioning systems from a future climate perspective. Split air conditioning in each room is common in Japan, but central air conditioning has recently become popular. Usually, dehumidification in domestic air conditioners is performed based on the total heat load. Therefore, in well-insulated buildings, dehumidification may be ineffective. Additionally, as latent heat load is expected to increase in the future, the split air conditioning systems may be unable to provide adequate thermal comfort. Finally, we analyzed the performance of central air conditioning systems in the typical Japanese house in a future climate context. Central air conditioning systems enable effective dehumidification, so the relative humidity in house will keep lower than that by split-room air conditioner and COP of central air conditioner is higher than that of split-room air conditioner.

【DESIGN 04: Parametric Design】

9th December, 1:30pm ~ 2:45pm

Session Chair: Daisuke Sumiyoshi, Kyushu University

Session Chair: Chengliang Fan, Guangzhou university

Acoustic Design Simulation of a Square-Plan Mosque Based on Optimization Using Fair-Weighted Scoring

Nur Alya Farrasti, R. Sugeng Joko Sarwono, Rizki Armanto Mangkuto
Department of Engineering Physics, Institut Teknologi Bandung, Indonesia

The parametric design method is an emerging approach for designing complex buildings, such as mosques. Designing a mosque's indoor space is challenging, as it must create a sacred and magnificent atmosphere while having acceptable acoustic quality. In Indonesia, many mosques feature a square-plan shape with a truncated pyramid ceiling, but no research has explored parametric design using simulation for optimizing acoustic conditions in such cases. This study aims to optimize mosque acoustic conditions while maintaining magnificence and good sound clarity by considering variations in ceiling geometry and material types using fair-weighted scoring. As a case study, a square-plan mosque was modeled using Rhinoceros 3D software, with acoustic simulations performed using Grasshopper and Pachyderm plug-ins. Three design variables were considered, namely the length and width (or area) of the truncated pyramid ceiling and the absorption coefficient of the ceiling material. These variables were varied to maximize reverberation time (RT), definition (D50), and speech transmission index (STI) values within specified ranges for each outcome variable. Optimization employs fair-weighted scoring methods. The derived solution set provides design recommendations for the truncated pyramid ceiling geometry that satisfies the required acoustic conditions. There are 10 design recommendations for ceiling with acoustical tile in scenarios with open doors and 10 design recommendation in scenarios with closed doors. For wood and concrete materials, additional treatment is required to meet the desired acoustic conditions.

Application of Three Transfer Learning Methods Based on YOLOv8 for Object Recognition in Architectural Drawings

Yuanze Feng[1], Daisuke Sumiyoshi[2]
[1]Kyushu University, Graduate School of Human-Environment Studies, Japan; [2]Kyushu University, Faculty of Human-Environment Studies, Japan

To meet Japan's 2050 carbon neutrality goal, it is essential to renovate existing buildings into Zero Energy Buildings (ZEB). Many of these buildings require renovations, and most existing architectural drawings are available only on paper. Thus, developing methods to digitize these architectural drawings, extract building information, and generate renovation plans automatically is crucial for improving efficiency. The YOLO model, widely used for image object recognition, effectively extracts necessary architectural data. However, models trained on architectural drawings from one company (Company A) often perform poorly on drawings from another company (Company B) due to stylistic differences. To avoid the increased workload of retraining the model solely on Company B's drawings, it is vital to generalize the model trained on Company A's drawings to other companies' drawings. This study aims to evaluate the effectiveness of three transfer learning methods—frozen layers, domain adaptation, and zero-shot learning—in generalizing object recognition in architectural drawings.

Numerical Study on the Effects of Active Heating and Passive Insulation of Pipe-embedded Wall Using Renewable Energy

Zhiyuan Zhang[1], Neng Zhu[1], Yingzhen Hou[1], Brian Considine[2], Aonghus Mc Nabola[2]
[1]School of Environmental Science and Engineering, Tianjin University, Tianjin, China; [2]Dept of Civil, Structural & Environmental Engineering, Trinity College Dublin, Dublin, Ireland

Thermally Active Building Systems (TABS) are innovative solutions designed to enhance energy efficiency and indoor comfort by utilizing the thermal mass of building structures. It can effectively reduce building energy consumption in winter. Most of the research on this concept to date has focused on its potential of saving building energy. However, most of the research does not discuss the reasons behind the thermal performance of building envelopes. This paper reports the dual thermal impacts of the building envelope. An experimental assessment was developed to investigate the building assemblies' thermal performance and the results were used to develop an understanding of its thermal energy-saving potential, and as an input for the validation of a numerical model of the same. A 3D computational fluid dynamics model of the pipe-embedded wall was developed by ANSYS Workbench to assess the thermal performance of the wall under boundary conditions beyond the capabilities of the experimental assessment. Further, the influence of several parameters including the outdoor temperature and pipe positions was studied. The results show dual thermal impacts of the wall: active heating and passive insulation. A method was proposed for selecting the pipe layer's optimal location based on the impacts. Using 8°C water reduces internal surface heat transfer by 42.5% under -20°C outdoor temperature conditions. This is akin to an 18°C outdoor temperature rise, and consequently a reduction in the building's energy consumption by 171W considering the circulation pump, which is equal to seven times the lighting consumption in a net-zero building. The findings of building physics provide guidelines for the further design of net zero energy building envelopes and the development of thermally active building systems in extreme cold climate conditions.

Optimum ventilation operation and design for thermal power station utilising both field measurement and simulation techniques

Takaya KASASHIMA[1], Ryohei FUJII[2], Yuichiro AMANO[2], Kentaro MATSUDA[2], Yasuhiro SHIMAZAKI[1], Masaki TAJIMA[1]
[1]Toyohashi University of Technology, Japan; [2]Shikoku Electric Power, Japan

This study establishes a practical model to be used for an optimal design and operational method to reduce energy consumption by controlling exhaust roof fans in a thermal power station to cool the internal space by introducing outside air. A new control procedure to optimise the number of fans in operation is presented by establishing a regression equation for estimating internal air temperature of the locations where the temperature is likely to be the highest, based on a combined analysis of simulation techniques and measurements. In this study, a regression equation for estimating internal air temperature is derived using the measurable variables with a certain accuracy. Under the conditions of this study, it is found that the setting of the wind pressure coefficient used in the theoretical calculation of the ventilation rate had a small effect on the accuracy of the regression equations.

Surrogate-assisted Passive Design Exploration of Residential Thermal Comfort in Multiple Climates

Ibrahim Elwy, Aya Hagishima
Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan

Enhancing thermal comfort in affordable housing through passive design strategies is crucial to minimize energy loads, environmental impacts, and operational expenses. The complexity of quantifying the effectiveness of various passive parameters on thermal comfort necessitates extensive exploration in various locations, typically relying on time-intensive physics-based simulations. Although surrogate models can enhance computational efficiency while accurately approximating building performance, their reliability diminishes in varying contexts, such as different climatic conditions. This paper aims to explore effective strategies for surrogate-assisted design space exploration of a residential room model located in tropical, arid, temperate, and continental climates. Eight passive design parameters are selected as inputs for an ensemble of five neural networks, each trained on EnergyPlus simulated datasets ranging from 32 to 4096 quasi-random samples per location. Given the impracticality of simulating the entire design space, the surrogate models are benchmarked against a higher fidelity model trained on 8192 samples. Analysis of Variance (ANOVA) is employed to evaluate models' robustness by comparing the statistical significance and contribution percentage of each parameter on thermal comfort variations across locations. Results indicate that using 512 samples significantly reduces computation time for simulations, while maintaining high accuracy for the test set (R2 = 0.989, MAPE = 7.38%). The selected model is then combined with self-adaptive differential evolutions algorithm with ensemble of mutations (jEDE) to optimize thermal comfort, achieving a median computation time of 26 seconds per 2500 evaluations. Despite the model's accuracy, significant relative errors within optimal solutions underscore the need for adaptive sampling to refine the surrogate model in promising areas of the design space. Overall, the proposed approach demonstrates potential for passive design exploration of similar housing settings in diverse climates, with the possibility of evaluating additional performance indicators, such as energy loads and lifecycle costs.

【DIGITAL 02: Big Data】

9th December, 1:30pm ~ 2:45pm

Session Chair: Fu XIAO, The Hong Kong Polytechnic University

Session Chair: Chaoqun Zhuang, Nanjing Tech University

Data-Driven Predictive Modeling and Anomaly Detection for Photovoltaic System

Ka Tai LAU, Sammy, Sau Kuen YEUNG, Pok Man SO, Ka Chuen YIP
The Electrical and Mechanical Services Department, HKSAR CHINA

This paper introduces a cost-effective, data-driven framework for the maintenance of photovoltaic (PV) systems in Hong Kong (HK), addressing the surge in installations following the 2017 FiT Scheme. Although PV systems are generally low-maintenance, regular upkeep is vital due to defects that can impair output and safety. Current reactive maintenance practices focus only on electrical components and overlook comprehensive monitoring, which is insufficient to given challenges such as degradation and environmental impacts. Our framework utilizes existing network infrastructure and open data from the HK Observatory to offer a scalable solution for urban areas. By integrating local and regional weather data, and PV parameters, we achieve centralized cloud monitoring and anomaly detection without extra installation. A GRU model, optimized through tailored by prediction timeframes, feature engineering, and hyperparameter tuning. This model reduces the mean absolute error by 30% and maintains a maximum weekly error of 1.85%, surpassing traditional models. A dynamic alarm method enhances fault detection, ensuring rapid, accurate anomaly identification. Validation in real-world scenarios confirms its effectiveness. The cloud-based design allows quick deployment across similar urban sites, supporting sustainable PV management and maximizing solar energy generation in HK.

DataNet Project: A framework for linking multi-faceted building energy datasets for effective performance analysis

Hye Gi Kim, Hye Ry Shin, Deuk Woo Kim
Korea Institute of Civil engineering and building Technology, Korea, Republic of (South Korea)

This paper introduces a framework of the DataNet project for gathering and linking multi-faceted building energy datasets nationwide in South Korea. The project's ultimate goals are twofold: (1) to establish a national data framework for accelerating carbon neutrality in the building sector, and (2) to support more effective, evidence-based performance gap analysis. The latter is an important issue under discussion in the IBPSA community, and the approaches and datasets developed may help achieve a breakthrough. Recently, administrative registration datasets (e.g. building registry, monthly energy billing information, building footprint polygon, business registration data, ministry-maintained facilities data, weather data, etc.) are public or partially open. However, from a building perspective, they are completely fragmented, because they are by-products of administrative processes that were not designed to be linked. In this project, each building register is set as a reference datum, and the others are linked at the national level using address and associated information, such as building or business name. Currently, 9 out of 19 datasets have been collected and are in the process of being linked. This paper briefly presents the overall framework, data categories, resolution, and linkage approach. It also discusses the challenges of the data linkage process, and the future applications of urban simulation and evidence-based performance gap analysis, which may require such multi-faceted datasets.

Enhancing Scalability of Neural Networks for MPC by Interconnecting Building Dynamics

Jeeye Mun, Hyeong-Gon Jo, Seongkwon Cho, Cheol Soo Park
Seoul National University, Korea, Republic of (South Korea)

For data-driven model predictive control (MPC) to be widely adopted in building applications, "scalability" is regarded as one of the imminent challenges. Many studies show that the data-driven models perform well under seen data but often fail in predicting beyond the training dataset or under unseen data. To enhance such scalability, the models must be able to learn fundamental physical principles or causality (not correlation) between inputs and outputs, thereby improving their extrapolation capability. In response to this challenge, this study aims to develop a physics-informed data-driven model for an office space served by a heat pump system. We propose a novel physicsinformed modeling approach leveraging neural network (NN) architectures, named NN implanted state-space model (NNiSS). The model predicts temperatures of indoor air, HP return air, and HP supply air with a time horizon of 30 min. The performance of NNiSS was compared with the three other NN-based models, each differing in the degree of dynamic interconnectedness: Multi Inputs Single Outputs (MISO)-NN, Federated MISO-NN, and Multi Inputs Multi Outputs (MIMO)-NN.
The results demonstrate that NNiSS consistently outperforms in predicting the system's dynamic behavior beyond the trained inputs. NNiSS's potential scalability across varying environmental conditions emphasizes the importance of designing a building thermal model based on dynamic interrelationships, which can be realized by integrating NN to a state-space representation.

Impact of dataset size to transfer learning model for predicting air temperatures of buildings with electrochromic glass

Thanyalak Srisamranrungruang[1], Kyosuke Hiyama[2]
[1]The Organization for the Strategic Coordination of Research and Intellectual Properties, Meiji University, Japan; [2]School of Science and Technology, Meiji University

The transfer learning (TL) technique is a method to transfer a training model of a building that has big data to another building that has limited data for evaluating building performances. In a building, a common but very important parameter used to identify building status is indoor air temperature. Prediction of indoor air temperature in advance can help to improve the stability of thermal comfort and reduce energy consumption. This study aims to investigate the impacts of dataset size of transfer learning to forecast indoor air temperatures at various times ahead from real-time to 5 hours for buildings integrating with electrochromic glazing. The training and test data use simulated results by building simulation software - Design-Builder, and the machine learning model - multilayer perceptron (MLP) is developed on MATLAB. The relationship between dataset size and the accuracy of transfer learning models by varying local climates and building orientations is analyzed. The source building model is located in Tokyo, Japan. The target building model is tested in two different locations, Tokyo and Fukuoka, Japan. The performances (RMSE) of the MLP model of the source building construct from 3-year data varied from 0.03 to 0.94. This study presented TL models that demonstrated superior performance compared to directly using a pre-trained model for predicting indoor air at various times ahead. This study discovered that TL models trained on one year of data are highly effective, with RMSE values ranging from 0.06 to 1.45, even when applied to target buildings situated in different cities and with varying orientations compared to the pre-trained model.

【FUTURE 02: District Energy System】

9th December, 1:30pm ~ 2:45pm

Session Chair: Xin Zhou, School of Architecture, Southeast University

Session Chair: Martin Mosteiro-Romero, TU Delft

Towards a Full Data Driven Coupled Scheme to Simulate Interactions Between Buildings and Their Outdoor Conditions at the City-Scale

Miguel Martin[1], Marcel Ignatius[2], Mario Berges[3], Joie Lim[2], Yijun Lu[2], Ruohan Xu[2], Clara Garcia Sanchez[1], Jantien Stoter[1], Nyuk Hien Wong[2]
[1]Delft University of Technology; [2]National University of Singapore; [3]Carnegie Mellon University

This paper suggests a method to simulate interactions between buildings and their outdoor conditions at the city-scale using a coupled scheme whose physical parameters are entirely assessed from data of the indoor and outdoor built environment. The coupled scheme consists of a reduced order building energy model and a single layer urban canopy model. In a previous study, it was proven that physical parameters of a single layer urban canopy model can be assessed using measurements of the outdoor temperature and humidity in a street canyon. For the coupled scheme to be fully data driven, the next step is to demonstrate that the reduced order building energy model can estimate the cooling consumption and exterior wall surface temperature in good agreement with measurements or simulated data after being trained using machine learning. Indeed, results show that a multi objective genetic algorithm can find values for physical parameters of the reduced order building energy model. Estimates of the cooling consumption and exterior wall surface temperature provided by the trained model achieve a CV-RMSE below 10% and a RMSE lower than 2.5 Kelvin, respectively, with respect to data generated from EnergyPlus. The last step towards a full data driven coupled scheme for city-scale simulations would be to iteratively train the reduce order building energy model with the single layer urban canopy model and show the convergence and accuracy of their respective outputs.

Feasibility study of 5GDHC plant in Tokyo using renewable energy sources

Kazuki Takiuchi, Shohei Miyata, Yasunori Akashi
The University of Tokyo, Japan

District heating and cooling (DHC), which can operate at high efficiency due to centralized chilled and hot water supply, is expected to greatly reduce CO_2 emissions because it can use heat sources other than fossil fuels. In recent years, heat source water networks that make maximum use of geothermal heat, etc., have been the focus of attention and research as 5th generation district heating and cooling (5GDHC) systems in cold regions of Europe. However, while DHC in Europe is supplied to residential buildings in cold regions, Tokyo in Japan is relatively warm and DHC generally supplies to commercial buildings. Therefore, the purpose of this research is to examine the feasibility of 5GDHC in Tokyo. In this research, we first developed a simulation model of a hypothetical 5GDHC system that assumes the supply of chilled and hot water to four buildings with different uses. The model takes as inputs the climate of Tokyo and the heat loads, and consists of water-source heat pumps for each building, a heat source water network, and a plant that maintains the temperature of the heat source water appropriately. Simulation of the base case with air-source heat pumps as the plant showed that the demand for both chilled and hot water offset each other during the intermediate season, increasing efficiency. However, system efficiency decreased during summer and winter due to fluctuations in heat source water

temperature. Based on the above, a new plant incorporating solar heat utilization will be simulated and compared to the baseline. Optimization of plant operations, such as the temperature setpoint of the heat source water, will also be attempted. This study will allow us to examine the feasibility of 5GDHC in Tokyo and the lessons learnt are expected to be expanded to other regions in Japan.

Optimization of Neighborhood-Scale Photovoltaics and Battery Implementation and Estimation of CO2 Emission Reduction

Momoka Tsujii[1], Yasunori Akashi[1], Kazuki Wada[2]
[1]School of Engineering, The University of Tokyo, Japan; [2]Takenaka Corporation

The use of renewable energy, such as photovoltaics (PV), is key to achieving carbon neutrality (CN), but urban areas often face disparities in renewable energy potential due to geographical conditions. Neighborhood-scale energy management can help bridge this gap, yet practical methods and their effects require further exploration. This study proposes methods for implementing PV and storage batteries in a neighborhood scale, focusing on clusters of nearby buildings. It compares these neighborhood-scale methods—where panels and batteries are shared among buildings—against individual-scale methods. CO2 emission reductions are calculated using a dynamic CO2 emission factor. Results showed that neighborhood-scale implementation is more effective for CN, with varying effects depending on the geographical characteristics and electricity demands of each neighborhood. These findings could enhance the efficient adoption of renewable energy across society.

Building Attached Photovoltaic renovation potential for typical Asian urban area: a case study on Beijing

Jun Xiao[1], Hao Zhou[1], Yang Zhao[1,2], Ziqian Zhou[1], Borong Lin[1,2]
[1]Department of Building Science, School of Architecture, Tsinghua University, Beijing 100084, China; [2]Key Laboratory of Eco Planning & Green Building, Ministry of Education, Tsinghua University, Beijing 100084, China

Along with the development on photovoltaic industry, Building Attached Photovoltaic (BAPV) application become one of the important sessions on urban renewal. Considering the potential in District Energy Storage System, the regional energy balance would be an essential evaluation for the urban design and planning decision on community BAPV renovation. In this research, the combination BAPV renovation strategies on building façade, roofs and street were evaluated on a high-density area in Beijing, China. A Bayesian-based calibrated Urban Building Energy Model (UBEM) was applied to simulate the regional energy demand based on a dataset for monthly electricity consumption of 3,442 buildings. The consumption was compared with the solar potential calculation. Storage schedule was calculated based on the hourly generation and consumption result, to provide brief budget estimations on different strategies combinations. As a conclusion, the energy demand mismatched the rooftop solar energy potential, but was highly compatible with the façade PV generation, which could provide an annual Self-Sufficiency up to 0.7. On the other hand, the unit budget for Façade PV system was 2.0 times higher than the rooftop system due to the higher reconstruction cost on the building façade compared to the roof. It was suggested that currently the rooftop and street BAPV was still a practical choice, however façade BAPV would have better compatible with high-density area.

【HUMAN 02: Thermal Comfort】

9th December, 1:30pm ~ 2:45pm

Session Chair: Jae-Han Lim, Ewha Womans University

Session Chair: Beom-Jun Kim, Hanyang University

Comparative Analysis between Field Study and ASHRAE-55 Adaptive Model of Thermal Comfort Perception in a Residential Building in Jakarta, Indonesia

Yuninda Mukty Ardyanny[1], Yasuhiro Shimazaki[2], Masaki Tajima[2], Zurnalis -[2]
[1]Universitas Multimedia Nusantara, Indonesia; [2]Toyohashi University of Technology, Japan

The thermal comfort perception of the occupants in a hot and humid climate may differ from others in the different climatic region. The aim of this research is to compare the thermal comfort perception by the occupant input of thermal sensation vote (TSV) acquired through the field study in a residential house in Jakarta, with the ASHRAE-55 Adaptive Model to see the discrepancy between them. This research also aims to compare the cooling energy needed to maintain the comfort temperature based on the ASHRAE-55 Adaptive Model and the field study data analysis, to see the possibility of cooling energy reduction based on a case study assumption of a typical 1-storey residential house in Jakarta. This research reveals if the actual field study data presents a wider range of comfort temperature compared to the ASHRAE-55 Adaptive Model (Up to 1.6oC higher). While based on the energy simulation in a typical Jakarta house assumption, the cooling energy can be reduced by 22% while still maintaining comfort based on the neutral operative temperature derived from the field study data analysis.

Development of a climate chamber reproducing real and simulated heating spaces for thermal comfort evaluation

Yasuda Shohei[1,2], Asawa Takashi[2], Miyanaga Toshiyuki[1], Ueno Tsuyoshi[1]
[1]Central Research Institute of Electric Power Industry, Japan; [2]Tokyo Institute of Technology, Japan

For enhancing energy conservation and thermal comfort in housing, thermal comfort should be evaluated by considering the non-uniformity of the thermal environment. This study develops a new climate chamber that considers such non-uniformity enabling the evaluation of energy-saving measures aimed at improving thermal comfort. Furthermore, if the developed climate chamber can simulate the thermal environment of a virtual house in its design stage based on simulation data, the thermal comfort of various energy-conservation measures can be evaluated. Therefore, in this paper, as a basic study to evaluate the virtual house, a computational model of the climate chamber was constructed, and the reproducibility of the simulated environment using the computational model was verified by comparing the measured and simulated values of the climate chamber.

From Sight to Sensation: Understanding Visual Elements' Impact on Thermal Comfort via Computer Vision and Thermal Voting

Lujia Zhu[1], Holly Samuelson[2], Nyuk Hien Wong[1], Yu Qian Ang[1]
[1]College of Design and Engineering, National University of Singapore; [2]Graduate School of Design, Harvard University

Outdoor thermal comfort plays a crucial role in determining the quality of urban spaces. While research has led to the development of heat indices, such as the Universal Thermal Climate Index (UTCI) and Physiological Equivalent Temperature (PET), these may not fully capture the complex, multisensory nature of thermal comfort as experienced by users. Recent studies have highlighted that visual elements significantly influence outdoor thermal comfort, yet their exact impact remains unclear. This study presents a novel approach to identify key visual elements and understand their impact on thermal comfort in tropical Singapore. We captured 135 photographs at the National University of Singapore and selected a diverse subset based on low similarity scores using computer vision models. We then quantified various visual element indicators in these images and used them for thermal sensation voting with students on campus. A tree-based ensemble model (Random Forest) was fitted to the indicator values and voting outcomes to determine feature importance. Our results provide a deeper understanding of the specific visual elements that influence outdoor thermal comfort and the magnitude of their impact. This knowledge will inform future outdoor thermal environment design, enabling the creation of more comfortable urban spaces.

Impact of Street Aspect Ratio and Building Configuration on Urban Thermal Comfort and Pollutant Dispersion

Xue Zhou[1], Xu Li[1], Lina Yang[2], Tiantian Xu[1], Jizhou Liu[1], Jiying Liu[1]
[1]Shandong Jianzhu University, Jinan 250101, China; [2]BinZhou Polytechnic, Binzhou 256603, China

Urban heat island effect is becoming more and more serious, which has many negative effects on urban environment and human health. The aspect ratio of street has significant influence on the air quality and thermal comfort of street microenvironment. This paper uses ENVI-met modeling and traditional two-sided street tree configuration to study the thermal comfort and pollutant diffusion capacity in street microenvironment under different building configuration with a height to width ratio of 0.27, 0.31, 0.35, 0.42, 0.43 and 0.5, respectively. The effects of street aspect ratio and building configuration on thermal comfort and pollutant diffusion capacity of street microenvironment were summarized. The results show that the thermal comfort of street microenvironment increases by 0.27℃ with the increase of building aspect ratio when the buildings are of equal height on both sides. The building configuration of upwind buildings with higher height than downwind buildings is more conducive to the diffusion of pollutants in the street microenvironment.

Personalized Thermal Comfort Prediction Modeling Based on Transfer Learning with Domain Adaptation

Chuangkang YANG, Keiichiro TANIGUCHI, Yasunori AKASHI
The University of Tokyo, Japan

In the field of building indoor environment research, thermal comfort is always significant topic. This study introduces an unsupervised transfer learning approach using a Dynamic Adversarial Adaptation Network (DAAN) for personalized thermal comfort prediction. The DAAN model leverages adversarial learning to reduce distribution discrepancies between a labeled source domain and an unlabeled target

domain, effectively predicting thermal comfort without labeled target data. Using a chamber experiment dataset, the DAAN model outperforms the base CNN-LSTM model in thermal preference prediction. The results highlight DAAN model's efficiency and scalability, demonstrating its potential for personalized thermal comfort prediction in building environments.

【SYSTEM 03: Ventilation】

9th December, 1:30pm ~ 2:45pm

Session Chair: Cheng Fan, Shenzhen University

Session Chair: Fatemeh Salehipourbavarsad, Czech Technical University in Prague

Determination of optimum settings for a hybrid ventilation system using TOPSIS score considering IEQ and energy requirements

Ken Bryan Alegre Fernandez[1,2], Kazuki Kuga[1], Kazuhide Ito[1]
[1]Kyushu University, Japan; [2]University of the Philippines Diliman, Philippines

Previous studies on hybrid personalized ventilation systems have placed less emphasis on the effects of main ventilation settings, even though these settings significantly impact the overall flow and scalar distributions indoors. Additionally, hybrid ventilation studies have primarily focused on air quality and have seldom included the concepts of thermal comfort and energy efficiency in the analysis, despite their importance in the design of total HVAC that constitutes the built environments. Therefore, this study aims to incorporate near-ceiling ventilation settings into the analysis and conduct simultaneous analysis of thermal comfort (average skin temperature), air quality (occupant inhaled CO2 concentration), and energy requirements in an office room with two occupants using computational fluid dynamics. Utilizing the Taguchi design of experiment, variables such as ceiling ventilation supply inlet temperature (16–21°C), flow rate (30–110 L/s), and recirculation (0.20 to 0.80) were varied along with personalized ventilation supply flow rate (0–6 L/s) and temperature (21–25°C). The "technique for order preference by similarity to ideal solution" (TOPSIS), a method for combining the three output parameters into a single objective function and determining how far the solution is from the ideal (TOPSIS score), was used for optimization. Results showed the highest objective function value of 0.98 with an average inhaled CO2 concentration of 816 ppm (below 1000 ppm), average skin temperature of 33.5°C (within the neutral skin temperature range of 33.6°C ±0.5°C), near-ceiling ventilation energy requirement of 0.05 kW, and average personalized ventilation energy requirement of 0.00 kW. The procedure successfully identified settings that provided acceptable thermal comfort and air quality at low energy requirements.

Development of natural ventilation control strategy for mixed-mode residential building using adaptive comfort model

Yulu Chen, Akihito Ozaki, Younhee Choi, Xianzhe Yang, Yusuke Arima
Kyushu University, Japan

Natural ventilation is an effective method to ensure indoor thermal comfort and reduce the energy consumption of air conditioning systems in mixed-mode buildings. Existing studies based on fixed set-point judgments provide limited guidance on natural ventilation control strategies, as human thermal comfort is adaptive to the outdoor environment. The adaptive approach suggested by ASHRAE Standard 55-2020 offers a variable comfort range for more appropriate control.

A few researchers are developing natural ventilation strategies using adaptive models. The common control method they use primarily involves reducing the natural ventilation comfort area to increase the comfort ratio during the operation of the control strategy. While this method can improve the comfort time for occupants, it may overlook the potential of natural ventilation. Therefore, this study aims to

develop an advanced adaptive controlled natural ventilation strategy with a higher natural ventilation rate and energy savings rate.

In response to the above issues, this study proposed a natural ventilation control strategy with more natural ventilation time for residential buildings based on the comfort zone of the adaptive model, aiming to save more energy for the air conditioning system. Mechanical ventilation or air-conditioning control is considered when natural ventilation conditions are not met, and the upper limit of the adaptive thermal comfort range determines the set points. The energy-saving effects of the developed strategy were examined through annual simulations on a Japanese standard house. The simulations used Tokyo's meteorological conditions and compared the proposal's performance with existing models. The simulation results demonstrated that the proposed natural ventilation strategy significantly reduces energy consumption and provides excellent thermal comfort, offering practical benefits for residential buildings.

Natural ventilation operation method to investigate the compatibility between IAQ and thermal environment in school buildings

Keiichiro Taniguchi[1], Yuichi Marukawa[2], Yoshikatsu Kokubun[2], Yoshimitsu Kamiyama[2], Yurika Bandai[2]
[1]The University of Tokyo, Japan; [2]Fuji Industrial Co., Ltd.

Since the onset of COVID-19 pandemic, ensuring indoor air quality (IAQ) in schools has become an important issue. Many older school buildings in Japan are not equipped with mechanical ventilation systems and rely on natural ventilation by opening windows to ensure IAQ. However, the combination of natural ventilation and air conditioning systems faces the difficult task of ensuring IAQ and maintaining a comfortable thermal environment. Therefore, it is necessary to develop an appropriate window operation method for school buildings.

We have been continuously conducting field measurements in a high school since the beginning of the COVID-19 pandemic. In 2022, the emphasis on ventilation resulted in Predicted Mean Votes (PMVs) far outside the comfort range; most of the time, classes were held in the summer and students' concentration and health may have been impaired. In 2023, natural ventilation was not effectively implemented based on the previous year's experience, and students were faced with IAQ problems for many hours as CO2 concentrations exceeded the Japanese school standard of 1500 ppm. Therefore, to investigate the compatibility of IAQ and thermal environment, multi-objective optimization calculations were performed using CFD analysis by varying the number and position of open windows. The effectiveness was validated through field measurements conducted in the winter of 2024 by advising teachers on the optimal window operation. As a result, the IAQ significantly improved, and the thermal environment was maintained at the same level as that in 2023. This result indicates the potential of solving the IAQ and thermal environment problems faced by many schools. In the future, we will explore more effective window operation systems that utilize sensor data.

Optimization Design Approach for Component Parameters in Space Station Ventilation Systems Using Flowmaster

Wenzhe Shang, Tianyu Zhao, Hejiang Sun, Junjie Liu
School of Environmental Science and Engineering, Tianjin University, Tianjin, People's Republic of China

Due to the challenges of post-installation adjustments and the higher failure rate associated with electric valves, which also contribute to increased weight and other complications, single-hole restrictors are commonly used in the ventilation system of manned space stations. These restrictors are pre-configured with parameters to ensure that airflow at the system's endpoints meets the required specifications. However, as these restrictors cannot be adjusted after installation, it becomes crucial to perform an optimization design in the initial stages. Traditional design methods based solely on experience often fail to guarantee precise and optimal results. Although Computational Fluid Dynamics (CFD) simulations provide accurate insights, they face limitations in modeling large-scale systems and require extensive time due to multiple iterations. To address this, the present study proposes an optimization design method using faster Flowmaster simulations. By employing the Functional Mock-up Interface (FMI) protocol, the ventilation system model built in Flowmaster can be exported as FMU files and further optimized in Python using a genetic algorithm (GA), rapidly achieving a balanced system design through the adjustment of single-hole restrictor parameters. The results from CFD calculations validate the accuracy of the Flowmaster simulations. Key optimization objectives include the unbalance factor of the vents and the system's pressure drops. Post-optimization, the system's unbalance factor and total pressure drops were reduced to 5.51% and 5.99 Pa, respectively—significantly better than the outcomes achieved with CFD using empirical and trial-and-error methods. Additionally, computation time was reduced by 99.16%.

Study on the effect of targeted ventilation purification technology on pathogen aerosol removal in ward

Jiaxin Zhang, Sumei Liu, Junjie Liu
Tianjin Key Laboratory of Indoor Air Environmental Quality Control, School of Environmental Science and Engineering, Tianjin University, Tianjin 300072, China

Negative pressure isolation wards (NPIWs) can provide treatment for COVID-19 patients during a pandemic. However, breathing releases aerosols containing pathogens, resulting in a potential infection risk for health care workers (HCWs). Robust ventilation in NPIWs can potentially reduce the infection risk, but can also increase energy consumption. Therefore, it is important to decrease energy consumption in NPIWs. This study proposes TARGETING, a new index for assessing the targeting of ventilation systems. The air curtain ventilation (ACV) achieved better comprehensive benefits, with an TARGETING of 1.3 and energy saving is about 35.9-58.0%.

【SYSTEM 04: Cooling Optimization】

9th December, 1:30pm ~ 2:45pm

Session Chair: Zhe Tian, Tianjin University

Session Chair: Takao Katsura, Hokkaido University

A Study on a Solar Radiation Control System to Reduce Cooling Load of a Lunar Habitat

Taeyeon Kim[1], Hansol Lim[2], Seheon Kim[1], Jae-Hee Lee[1], Yong-Kwon Kang[1], Jae-Weon Jeong[1]
[1]Hanyang University, Korea, Republic of (South Korea); [2]Korea Institute of Civil Engineering and Building Technology, Korea, Republic of (South Korea)

As the Artemis program advances the development of a lunar habitat, ensuring thermal stability within the habitat emerges as a critical component of space exploration. Given that the Moon's lack of atmosphere makes solar radiation the dominant factor in its extreme thermal environment, causing significant heat loads due to drastic temperature fluctuations between lunar day and night. To mitigate this challenge, this study proposes a solar radiation control system using sunshades to efficiently reduce the cooling load of a lunar habitat. In this study, a simulation model is developed to evaluate the cooling and heating loads of a lunar base located at the equator, accounting for the solar radiation of the Moon. The results show that the proposed system can significantly reduce cooling demands, offering a practical and energy-efficiency solution for managing thermal loads in lunar habitats. These findings can contribute to future advancements in lunar base construction and operation.

Integrating Thermal and Battery Energy Storage with Solar Photovoltaics to Decarbonize Cooling Systems: Design Case Study for a University Hostel

Aviruch Bhatia[1], Shashikant Pawar[1], Vishal Garg[1], Jyotirmay Mathur[2], Srinivas Valluri[3]
[1]Plaksha University, Mohali, India; [2]Malaviya National Institute of Technology Jaipur, India; [3]Synergy Infra Consultants Pvt. Ltd, Hyderabad, India

The increasing demand for air-conditioning presents a critical challenge in reducing energy consumption and carbon emissions. Transition from fossil fuels to renewables is vital in aligning with climate objectives. Photovoltaic systems play an important role in this transition, as energy is readily available during the daytime, making it easier to decarbonize daytime loads. However, employing RE to meet the air-conditioning energy requirements of residential buildings, which largely occur during the night, poses a challenge. Energy storage which can be charged during daytime, when clean energy is available and discharged during nighttime can address this issue. This paper discusses aspects of design of a phase-change-material based thermal-energy-storage to cater to nighttime cooling requirements of a testbed in university hostel. The case study building is located in Mohali, India, having a subtropical climate with hot summers. The building has a total of 10 floors with 224 rooms. Presently cooling energy is supplied to the hostel rooms using a central chilled water system with each room having a fan-coil unit. Peak load and sizing of the energy storage system are determined through energy simulation. Thermal storage sizing is done based on total nighttime cooling requirements and the daytime availability of solar energy. A low-temperature chiller is selected to cool the brine which in turn is used to store energy in ice as a Phase Change Material (PCM). To decarbonize the electricity used by indoor units and chilled water pumps of air conditioning, battery energy storage system is designed. This solution not only aims to mitigate carbon footprint but also offers economic benefits by capitalizing on off-peak electricity tariffs in solar hours. Implementation strategies and challenges are discussed, providing valuable

insights for similar residential contexts, and contributing to environmentally conscious and economically viable solutions.

Machine learning-based model predictive control optimization method for ice-storage cooling system in a super high-rise building

Wenbo Qiang[1], Chenwei Peng[1], Jiewen Deng[2], Qingpeng Wei[1], Anqi Zhong[3]
[1]Department of Building Science, Tsinghua University, Beijing, P.R. China.; [2]School of Environmental Science and Engineering, Huazhong University of Science and Technology, Wuhan, Hubei, P.R. China.; [3]China Academy of Building Research, Beijing, P.R. China.

With the promotion of peak-valley electricity pricing, an increasing number of large commercial buildings are adopting ice-storage systems for space cooling. This paper conducted field tests for the operational performance of an ice-storage system in a commercial building located in the hot summer and warm winter region of China. The results indicate that the-ice storage system is hindered by a lack of guidance, resulting in an annual average cooling cost of 0.194 RMB/kWh. During transitional seasons, the system frequently experiences over ice-storage issues. In contrast, during peak cooling periods, the system often suffers from insufficient ice storage and fails to fully utilize the peak-valley electricity pricing to save operational costs. Therefore, this paper proposes an easy-to-apply cooling load prediction model based on the XGBoost method, combined with thermodynamic principles. The input parameters of the model are easily obtainable, including environmental meteorological conditions, time attributes, and the cooling load of the previous moment. Furthermore, this paper introduces an updated control method for the ice storage system using the proposed prediction model. The results of actual operation validate the effectiveness of the proposed model predictive control method, achieving a significant electricity saving rate of 41.9% and reducing the cooling cost to 0.111 RMB/kWh.

Passive cooling strategies to enhance the resilience design of a cooling shelter in India

Yi Wu[1,2], Jeetika Malik[2], Elif Kilic[3], Prasad Vaidya[4], Tianzhen Hong[2], Da Yan[1], Ashok Gadgil[3]
[1]Tsinghua University School of Architecture, China; [2]Building Technology and Urban Systems Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA; [3]Department of Civil and Environmental Engineering, University of California Berkeley, Berkeley, CA, United States; [4]Indian Institute for Human Settlements, Sadashivanagar, Bengaluru 560 080, Karnataka, India

India's 231 million outdoor workers are exposed to deadly heat during heat waves. We report early results from an ongoing study that focuses on passive design of cooling shelters for these workers across different climate zones of India. The goal is to design a cooler-than-outdoor shelter for outdoor workers' intermittent rest and recovery from heat stress during their arduous outdoor work, to avoid heat-related morbidities and mortality. Expected indoor thermal conditions in low-cost cooling shelters deploying a range of passive designs are investigated, consistent with the current Indian standards and practices, located in the hot and arid city of Jodhpur, India. The indoor thermal conditions were simulated using EnergyPlus. We evaluated the effectiveness of various passive and low-energy active measures in improving thermal resilience of the shelter. The resilience was measured via the predicted reduction of hazardous hours based on the wet-bulb globe temperature. These measures include improving the building envelope, installing cool roofs, using internal thermal mass, and natural ventilation. Additionally, a low-energy active measure of using ceiling fans is considered. Simulation results show that combined passive measures can significantly reduce indoor heat stress compared to outdoors during the hottest hours of the day in a heat wave. The outcomes can inform cool shelter designers and policymakers on the deployment of affordable resilient cooling shelters for vulnerable outdoor workers

during heat waves in India.

Low energy cooling for semi outdoor spaces on an academic campus

Kai Zheng, Aceson Han, Tzai Yun Cheng, Janessa Kwan
Singapore University of Technology and Design, Singapore

This study investigates the implementation of a dry mist evaporative cooling system in a semi-outdoor area on the campus of the Singapore University of Technology and Design, specifically a space outside a lecture theatre designed for cross ventilation. Singapore's hot and humid climate, combined with good natural ventilation at the chosen site, provides an opportunity to explore evaporative cooling despite challenges posed by high relative humidity. The study focuses on optimizing dry mist deployment through computational fluid dynamics (CFD) simulations, with the aim of enhancing thermal comfort without the use of additional fans. A mesh sensitivity study was conducted to determine the optimal computational grid for the simulation, and natural ventilation was studied using prevailing wind directions from the north and south. Wing walls were introduced to redirect wind towards areas where airflow was obstructed, improving natural ventilation in stagnant zones. The core of the study explores the effects of dry mist deployment under various configurations. Simulations showed that lower wind velocities allowed the cool air from misting to settle more effectively, while high wind velocities rapidly replenished the ambient air, limiting cooling effectiveness. The study concluded that using multiple nozzles with lower mass flow rates was more effective than single high-flow nozzles, as this configuration better distributed the cooled air across the site. Additionally, strategically placed wing walls enhanced the system's performance by directing wind to key areas. The results offer practical insights into the deployment of dry mist systems in semi-outdoor spaces in tropical climates, optimizing both thermal comfort and water usage.

Monday, 9th December, 3:15pm ~ 4:30pm

【DESIGN 05: Envelope】

9th December, 3:15pm ~ 4:30pm

Session Chair: Steve Kardinal Jusuf, Singapore Institute of Technology

Comparison of pseudo unsteady-state and fully unsteady-state thermal exergy analyses for internally and externally insulated building envelopes

Habin Jo[1], Young-sang Kim[3], Masanori Shukuya[4], Wonjun Choi[1,2]
[1]Department of Architecture and Civil Engineering, Chonnam National University, Gwangju, Korea; [2]School of Architecture, Chonnam National University, Gwangju, Korea; [3]Department of Civil Engineering, Chonnam National University, Gwangju, Korea; [4]Department of Restoration Ecology and Built Environment, Tokyo City University, Yokohama, Japan

The pseudo unsteady-state (PU) and fully unsteady-state (FU) exergy analysis methods consider variations in boundary conditions and environmental temperature. The PU method, based on a steady-state governing equation, neglects transient phenomena. In contrast, the FU method, based on an unsteady-state partial differential equation, provides more realistic results by full considering transient phenomena. However, the FU method requires more computational resources due to its complex numerical calculations. Therefore, application of the PU method can minimize computational load in systems where transient effects are insignificant, making the difference between PU and FU methods acceptable. Building envelopes typically consist of concrete and insulation layers which have greatly different thermal characteristics. As a result, the thermal behavior varies significantly depending on the arrangement of insulation, and the discrepancy between PU and FU methods can vary according to transient phenomena. This study examines two building envelopes consisting of 15 cm concrete and 5 cm insulation layers: one internally insulated and the other externally insulated. The results indicate that for the internally insulated envelope, the FU method should be applied due to the intense transient phenomena. In contrast, for externally insulated envelopes, the discrepancy in exergy results between the two methods is acceptable due to insignificant transient phenomena.

Towards Independent Adjustment Technologies for Thermal Insulation and Shading in Transparent Building Envelopes: A Systematic Review and Future Prospects

Xiaoyang Lv, Qinglin Meng, Huijun Mao, Junsong Wang
South China University of Technology, China, People's Republic of

Traditional static transparent building envelopes cannot meet the demands for climate adaptability and dynamic indoor environmental control, resulting in high building energy consumption, poor thermal comfort, and other problems. As a result, adjustable transparent building envelopes have attracted increasing attention from researchers and industry professionals. Heat transfer coefficient (U-value) and solar heat gain coefficient (SHGC) are two critical factors that determine the thermal insulation and shading performance of transparent building envelopes, influencing the indoor thermal environment. Although various adjustable technologies targeting these factors have been studied, this study finds a significant gap in research on independent control with a comprehensive review of these technologies from the perspectives of materials and structural adjustments summarized. In response, this study introduces the concept of insulation and shading performance independent adjustment technology and proposes a preliminary structural design that can independently regulate insulation and shading performance. The simulation and analysis of this innovative system show that it has broad application prospects in response to changes in climate, seasons, and time of day.

Research on predictive models for building envelope heat transfer

Erlin Zou[1], Jihui Yuan[1], Zhichao Jiao[1], Craig Farnham[1], Zhe Tian[2], Xia Wu[2], Kazuo Emura[1]
[1]Osaka Metropolitan University, Japan; [2]Tianjin University, China

This paper investigates the application of predictive models for analyzing heat transfer through building envelopes, with the goal of enhancing energy efficiency and comfort in urban environments. The study focuses on two widely used predictive models: Linear Regression (LR) and Neural Networks (NN). These models were employed to simulate the thermal performance of a building envelope constructed to replicate typical urban structures. Experimental data were collected using a scaled-down building model equipped with thermocouples and solar radiation sensors, capturing temperature variations under real-world conditions. The LR model, known for its simplicity, provided a quick and moderately accurate estimation of internal surface temperatures. However, its accuracy was limited in scenarios involving non-linear interactions, such as sudden changes in solar radiation. In contrast, the NN model, with its ability to model complex, non-linear relationships, demonstrated higher accuracy, achieving a lower Mean Squared Error (MSE) compared to the LR model. The results suggest that while the LR model is useful for initial design stages, the NN model is better suited for applications requiring precise thermal predictions, particularly in complex urban settings. The study also highlights the challenges associated with predictive modeling, including the need for large datasets and computational resources, especially for NN models. The findings have significant implications for sustainable building design, emphasizing the importance of accurate heat transfer predictions in optimizing material selection and reducing energy consumption. This research contributes to the ongoing efforts to improve urban sustainability by providing insights into the effective use of predictive models in building envelope design.

Utilizing Solar-reflective Film on Window Glazing to Reduce Cooling Loads in Tropical Buildings

Shanshan Tong, Shuyan Zhang, Erna Tan, Marcel Ignatius, Nyuk Hien Wong
Department of Built Environment, National University of Singapore, Singapore

Heat transmission through windows significantly contributes to external heat gain in buildings, particularly in tropical climates. This study evaluates the energy savings and cost-effectiveness of applying solar-reflective film to window glazing in retrofitted buildings. A field experiment conducted on an institutional building in Singapore demonstrated that mean radiant temperature near the windows and short-wave radiation through windows can be reduced by up to 1.5°C and nearly 60% during the daytime respectively. Using building energy modeling (BEM), we assessed the thermal performance and potential energy savings of solar-reflective film in buildings with varying WWRs and façade shadings. A cost-effectiveness analysis further indicates that in cases with the absence of external shading or high SHGC glass, solar-reflective films can offer better economic returns.

Performance evaluation of net zero energy house utilizing passive design strategy

Xianzhe Yang[1], Younhee Choi[2], Akihito Ozaki[2], Kaoru Suehiro[2], Toui Hashiguchi[1], Yusuke Arima[2]
[1]Graduate School of Human-Environment Studies, Kyushu University, Japan; [2]Faculty of Human-Environment Studies, Kyushu University, Japan

In recent years, Japan has made significant efforts toward achieving a carbon-neutral society by 2050, with a strong focus on promoting Net Zero Energy Houses (ZEH) within the residential sector. Traditionally, ZEHs have primarily focused on improving energy savings through enhancements in building envelope performance, such as insulation and airtightness, as well as the integration of solar power systems and high-efficiency mechanical equipment. However, the potential for further enhancing energy efficiency by utilizing renewable energy sources, such as natural ventilation, has received limited attention.
This study investigates the performance of ZEHs employing passive design strategies that harness renewable energy. In addition to high-efficiency systems like heat recovery ventilation and solar panels, the building integrates passive design strategies aimed at enhancing indoor air circulation and utilizing natural ventilation to improve thermal comfort and energy efficiency, particularly during the summer and transitional seasons. Furthermore, these strategies are evaluated for their potential to reduce reliance on mechanical cooling systems and provide an alternative for energy savings in residential buildings. The research adopts a two-step approach to verify and evaluate the building's thermal performance. First, field measurements were conducted to gather empirical data. Second, heat load calculations were performed using an energy simulation tool to validate energy-saving performance. The findings emphasize the importance of natural ventilation and indoor air circulation in optimizing thermal performance and energy conservation, contributing to the refinement of ZEH design and promoting sustainable residential architecture. Additionally, the study provides new insights into balancing passive and active design elements in future residential buildings.

【DESIGN 06: Optimization of Design and Operation】

9th December, 3:15pm ~ 4:30pm

Session Chair: Shohei Miyata, The University of Tokyo

Session Chair: Sumei Liu, Tianjin University

A novel rule-based optimization approach for building energy profile dispatching in design-phase

Xuyuan Kang, Xiao Wang, Da Yan
Tsinghua University, China, People's Republic of

Building electrical system design with optimal component capacities plays a critical role in renewable energy utilization and carbon emission reductions. In the capacity optimization iterations, the ideal control strategy for different components is critical in evaluating whole-year operation costs. This study developed a novel rule-based algorithm for building energy profile dispatch. The components in building energy systems were categorized to four types, and the dispatch algorithms targeting curve-tracing and cost-minimization were proposed respectively. The performance of the proposed algorithm was cross-compared with two baseline models on an office building case. The proposed method achieved a 65% reduction on annual cost compared to the baseline models, while achieving the shortest computation time of 0.6 seconds. The proposed method can effectively support the capacity design of building energy systems.

The Simulation Tool and Predictive Model for Snow Drift in the Early-stage Design of Ice-Shell

Shuoyong Yang, Peng Luo
School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin 150001, China

Ice-shell architecture is a novel and widely used type of ice architecture supported by advanced structural and material technologies, offering new functionalities and operational modes. However, the climate adaptability of ice-shell architecture is compromised due to the susceptibility of composite ice to environmental factors, which affects its practical effectiveness. Design decision systems supported by parametric platforms and performance simulation data can optimize the design and enhance weatherability in the early-stage design. Nonetheless, the workflow is currently unfeasible because there is no tool available for simulating snow, a primary climatic factor in cold regions, during the early-stage design. The study aims to address the gap by extending the functionalities of the Grasshopper plugin Butterfly to invoke the two-phase flow solver in OpenFOAM, thereby creating an integrated snow drift simulation tool for the early-stage architectural design. The effectiveness of the tool will be validated through case studies and empirical testing on ice-shell buildings. The machine learning method will be introduced to meet the efficiency requirements of the design process. Feature analysis will extract ice shell morphological factors as features, while surface volume fraction, as simulated by the developed tool, will serve as the label. Training and testing sets will be established to train a predictive model for snow distribution on ice-shell architecture, thereby improving computational efficiency and enabling practical design applications. The study will support the optimization of weatherability in ice-shell architecture. Additionally, the simulation tool can be extended to the climate adaptability design of other buildings in cold regions.

Simulation and validation of indoor temperature and relative humidity in a mixed-mode ventilated building in a tropical climate

Siyu Cheng, Adrian Chong
National University of Singapore, Singapore

With increasing concern over indoor heat exposure due to heatwaves, there is a growing need for accurate predictions of indoor environment under complex, real-world conditions. Unlike building energy predictions, indoor temperature and humidity forecasting demands greater precision, as it requires capturing detailed profiles at specific time intervals. While model calibration is widely used to enhance model reliability, it has mainly focused on energy consumption. Limited efforts have been made to calibrate and validate models for simultaneous accuracy of indoor temperature and relative humidity. This paper presents a case study of a Mixed-mode Ventilation Living Lab in Singapore, where a multizone model is calibrated and validated to predict indoor temperatures, relative humidity, and cooling power consumption simultaneously. The calibrated model successfully captures both thermal and system dynamics during mode transitions. Results demonstrate that calibrating the Discharge Coefficient and Wind Pressure Coefficient in the Airflow Network (AFN) model is critical for accurately predicting wind-driven multizone airflow as well as indoor temperature and humidity patterns. Additionally, energy simulations must place greater emphasis on material thermal properties, especially those related to radiative heat gain, to enhance the accuracy of indoor temperature predictions.

Data Science for Performance-Driven Design Class: Past, Present, and Future.

Jung Min Han
Yonsei University, Korea, Republic of (South Korea)

In the rapidly evolving field of data science, educational methodologies must continually adapt to incorporate new technologies and approaches that enhance learning and application effectiveness. Since 2017, I have been teaching data science at architecture school and it has evolved for the past 9 years. The integration of data science principles into architectural education has seen transformative shifts, reflecting both emerging technologies and industry demands. This paper delineates the evolution and structure of an innovative data science course tailored for architecture students, emphasizing performance-driven design. The course, developed and refined over 9 years, equips students with essential skills to critically analyze and optimize architectural designs using advanced data analytics. The curriculum, detailed herein, covers key areas such as machine learning applications in architecture, simulationbased optimization, and real-time data integration in the design process. The pedagogical approach combines theory with practical, hands-on workshops, encouraging students to apply data science techniques directly to architectural design. Feedback and performance metrics collected since the course's inception indicate significant gains in students' analytical capabilities and their understanding of datadriven design principles. This paper discusses the iterative development of the course content and teaching methodology, providing insights into effective strategies for incorporating data science education within architecture programs. In addition, the collective projects across different schools and students' background are going to be compared with simple statistics projecting future adaptations.

【DIGITAL 03: Advanced Modeling】

9th December, 3:15pm ~ 4:30pm

Session Chair: Mao Serikawa, Kanagawa University

Session Chair: Kai Zheng, Singapore University of Technology and Design

A general few-sample model training assistant for building heating loads prediction

Xingyu Peng[1], Conghui Li[1], Yakai Lu[1], Zhe Tian[2]
[1]School of Energy and Environmental Engineering, Hebei University of Technology, Tianjin, China, People's Republic of; [2]School of Environmental Science and Engineering, Key Laboratory of Efficient Utilization of Low and Medium Grade Energy, MOE, Tianjin University, Tianjin, China, People's Republic of

To solve the challenge of predicting building heating loads with limited data, it's common to use abundant data from other buildings to create pre-trained models. These pre-trained models help train models for the target building. However, the success of these models depends on the quality of the source building data and its similarity to the target building. Obtaining high-quality source data separately for different target buildings is difficult in practice. This paper proposes a general few-sample model training assistant (FSMTA) for building heating loads prediction. Firstly, prototype building simulation models for the target building type are created, and a large amount of simulation data for buildings with different parameters is generated. Then, meta-learning methods are used to extract common features from the simulation data. The resulting meta-model is used as the FSMTA for the target buildings. The effectiveness of FSMTA is validated in the scenario of high-rise residential buildings in northern China using the MAML meta-learning method. The results show that compared to learning directly with a small amount of data from the target buildings, FSMTA reduces the prediction error by 48.15% to 58.64% in low-sample scenarios, demonstrating exceptional generalization while maintaining accuracy

Linked Deep Gaussian Process for Digital Twins in Building Energy Systems

Chaoqun Zhuang[1], Deyu Ming[2], Mingda Yuan[2], Nikolas Makasis[3], Monika J. Kreitmair[3], Ruchi Choudhary[1]
[1]Department of Engineering, University of Cambridge, United Kingdom; [2]School of Management, University College London, United Kingdom; [3]School of Sustainability, Civil & Environmental Engineering, University of Surrey, United Kingdom

Digital Twins have significant potential in managing building energy systems, reducing operational risks, improving energy efficiency, and achieving decarbonisation goals. Driven by data and models, digital twins can perform monitoring, simulation, prediction, and optimisation. The core of a digital twin lies in its robust modelling capabilities and its ability to seamlessly handle real-time data, accurately replicating the physical entity to provide functional services and meet application needs. Present modelling approaches often depend on physics-based models, which can be complex, computationally intensive, and require substantial physical knowledge. In contrast, purely data-driven black-box models often lack physical interpretability and may not effectively capture the underlying dynamics. This study hence proposes a Linked Deep Gaussian Process (LDGP) for digital twinning and building performance simulation. This method connects individual data-driven component models based on their physical associations and varying functional complexities, incorporating uncertainty propagation to quantify predictive errors. A four-pipe ground source heat pump system in a campus building at Cambridge is used as a case study to demonstrate the effectiveness of the modelling approach. Results show that the LDGP

can accurately model with reduced measurement data and thus contribute to enhancing digital twin modelling for building energy systems.

Required training data for grey-box model identification in buildings

Xinyi Lin[1], Zhe Tian[1], Adrian Chong[2], Yakai Lu[3], Jide Niu[1]
[1]Tianjin University, China, People's Republic of; [2]National University of Singapore, Singapore; [3]Hebei University of Technology, China, People's Republic of

Grey-box modeling has been widely applied in building load estimation, control and optimization, and building-grid-integration. The identification of grey-box model parameters relies heavily on how the training data is set. However, there is no consistent guidance for determining the required dataset. In this study, a novel index based on maximum mean discrepancy (MMD) is developed to evaluate the variety of training data distribution. Based on the index, experimental data for a wide range of scenarios are generated to analyze the impact of training data distribution on the quality of grey-box RC models. The results show that when using input data with a wider variation, the forecasting accuracy of the model is higher. The impact of training data length is also investigated. It is found that there is no clear relationship between training data length and model performance. These findings can provide practical guidance in the modeling of grey-box models.

Developing Thermal Comfort Models with Transfer Learning: Exploring the Data Requirements of Occupant-Centric Control

Kazuki Horikoshi[1], Eikichi Ono[2], Kuniaki Mihara[3], Takamasa Hasama[3], Adrian Chong[1]
[1]National University of Singapore, Singapore; [2]Kajima Technical Research Institute, Japan; [3]Kajima Technical Research Institute Singapore, Singapore

Occupant-centric control (OCC) strategies enhance comfort and energy efficiency through personalized adjustments but rely on accurate thermal comfort models, which are labor-intensive due to extensive survey requirements. This study explores using active transfer learning to reduce this effort by refining CNN-LSTM-based models with fewer surveys. We examined the impact of amount of learning data on predictive accuracy and energy efficiency across different HVAC control scenarios. Results show that adding the two most informative survey data enhances prediction accuracy by over 10%, and adding more surveys gradually improves accuracy, while selecting less informative data may even decrease it. Through the selection of informative instances, we observe each personal comfort model updating itself using the most informative points. Our building energy simulations reveal that adding survey data allows the control logic to adjust temperature setpoints more confidently, resulting in an 11% reduction in zone control and a 6% reduction in personal control. The findings of this work are particularly valuable for researchers focused on the practical development of data-efficient comfort models and their application to HVAC control.

A method to measure window opening areas by image processing technique

JunLiang Liu, Genku Kayo
Tokyo City University, Japan

Currently, energy management systems for intelligent buildings are mostly BEMS systems, which play an essential role in detecting and controlling the energy efficiency of buildings. However, they generally lack information about natural air exchange. Natural ventilation is an important factor in ensuring air quality and energy saving in buildings, and the area of window openings is critical information to determine the amount of natural ventilation. Traditional area measurement methods usually require multiple sensors, and the data collection process is cumbersome. This study proposes a method based on image processing technology to measure the window opening area by capturing the contour of the window opening using the OpenCV-python method. At the same time, the threshold value is adjusted by analyzing the results of different measurement situations to ensure measurement accuracy under various environmental conditions. The experimental results show that the contrast difference caused by light is the most influential factor, and by adjusting the relevant parameters and thresholds in the image processing technique, the accuracy of the measurement can be effectively improved, and this method can be used for practical measurements. This research result can help to obtain information about natural ventilation inside the building more efficiently and conveniently, and this OpenCV-based technique lays a foundation for future research on the prediction of indoor natural ventilation combined with machine learning.

【FUTURE 03: Grid Integrated Building Design and Systems】

Session Chair: Maomao Hu, National University of Singapore

Session Chair: YUKI MATSUNAMI, Takasago Thermal Engineering Co., Ltd.

Transfer Learning-Supported Building Electric Energy Forecasting Using Neural Network Models

Hongwen Dou, Kun Zhang
École de technologie supérieure, Canada

The operation data recorded in the Building Automation System (BAS) provides an untapped opportunity for developing data-driven models to improve building performance. However, BAS data might be insufficient to derive an accurate model for practical applications. For example, the data quality may be unreliable, and for new buildings or renovations, operation data may simply be unavailable. To tackle this problem, this paper investigates transfer learning to forecast cooling electricity demand and total building electricity demand using neural network models. The case study includes two buildings, a source building with synthetic data from an EnergyPlus model and a target building with real-world BAS data. A neural network model is first pre-trained with the synthetic data from the source building, and then transferred to the target building to forecast the electricity demand of the cooling system and the whole building. Compared with the model derived only from the BAS data of the target building, the transfer learning approach shows an improved forecasting performance by 40% and 44% respectively for the cooling and total building electricity demand. The transfer learning results could be further used in advanced controls such as model predictive control.

The accommodation potential of buildings and electric vehicles for urban roof PV power generation——a case study in Shanghai

Shuai Tian[1,2], Xing Shi[1,2], Ke Zhu[1,2], Xin Zhou[3]
[1]College of Architecture and Urban Planning, Tongji University, Shanghai, China; [2]Key Laboratory of Ecology and Energy-saving Study of Dense Habitat, Ministry of Education, Shanghai, China; [3]School of Architecture, Southeast University, Nanjing, Jiangsu Province, China

It is widely recognized that large-scale deployment of rooftop photovoltaics (RPV) is essential for meeting urban energy demands and achieving carbon neutrality. However, with the increase of installed renewable energy capacity, the capacity of the grid has become increasingly saturated, and the local immediate consumption of RPV energy has received more and more attention. Therefore, by leveraging multi-source big data and urban building energy modeling method, we simulated hourly rooftop PV output, building electricity consumption, and electric vehicles (EV) charging demand in Shanghai, China. Subsequently, the potential of buildings and EVs to utilize RPV energy production immediately was analyzed. The results indicated that Shanghai's RPV output was approximately 3.73 ×1010 kWh, and annual EV charging demand was 3.74 ×109 kWh. When using buildings and EVs separately to absorb RPV output, they can absorb up to 2.95 ×1010 kWh and 1.68 ×109 kWh, respectively. Moreover, buildings and EVs can immediately accommodate 80.07% of RPV output together. The conclusions revealed that buildings and EVs can effectively absorb RPV output. To further enhance the utilization of RPV output, the incorporation of demand side management methods and energy storage systems is necessary.

Performance simulation of flexible power grid strategies in typical residential blocks with multiple morphologies in Shenzhen, China

Yuqin Wang[1,2], Haida Tang[1,2], Chunying Li[1,2], Xiangyi Li[1,2]
[1]School of Architecture & Urban Planning, Shenzhen University, China, People's Republic of; [2]Shenzhen Key Laboratory of Architecture for Health & Well-being (in preparation), Shenzhen, China

Implementing energy-flexibility strategies for energy generation and consumption in different morphologies of residential blocks plays an important role in optimizing the use of renewable energy and response to grid demand. This research aimed to evaluate the impact of regional morphologies and flexible strategies on the energy performance of residential blocks. This paper extracted nine typical residential block morphologies in Shenzhen, China, and established a photovoltaic power generation and building energy consumption model through Radiance and Energy Plus. Three different strategies combining building load, photovoltaic, electric vehicle, and battery energy storage were proposed and evaluated in nine different morphologies of residential blocks. The research results indicated that the flexible strategy reduced energy, economic expense, and carbon emissions. And it achieved the greatest performance on grid power supply, levelized cost of electricity, and carbon emission in multi-story residential blocks. Flexible strategy demonstrates significant peak shifting effects in multi-story, small high-rise, and high-rise residential blocks. This study could provide measures for residential blocks to reduce energy consumption, electricity bills, and carbon emissions.

Optimized Operations of a Three-Battery System in a Smart Community

Tomohiro Takahashi, Masataka Yuasa, Hideaki Uchida, Yohei Yamaguchi, Yoshiyuki Shimoda
Osaka University, Japan

In urban planning for low-carbon and disaster-resilient communities, smart communities with decentralised energy systems have gained continuous attention. These systems integrate photovoltaic (PV) generation with batteries and fuel cells to mitigate the intermittency of PV. PV battery systems focus on optimal household-level operation and consider peer-to-peer energy trading for community optimisation. Another promising approach involves a three-battery system integrating PV, batteries, and solid oxide fuel cells. However, there is limited understanding of the complexity of controlling multiple energy sources (generation, storage, and thermal systems). Consequently, the control during actual operation tends to become rigid and uniform. This study proposes a comprehensive and adaptive control scheme for a three-battery system. Moreover, it explores system optimisation at both household and community scales. We developed a model to simulate the behaviour of a three-battery system based on inputs of electricity and hot water demand, and PV generation.

We expanded the conventional control schemes by proposing 6 control cases for household energy management and 13 control cases to promote community-level electricity purchases. Genetic algorithms (GA) were employed to minimise CO_2 emissions and costs by identifying the optimal combination of control cases for each household at every time step.
Consequently, CO_2 emissions were reduced by 3.1% and 5.2% at the household and community levels, respectively, while variable costs were reduced by 8.3% and 9.5%. Power sharing in community-level optimization proved more effective.

This highlights that in the CO_2 optimization scenario, grid electricity was utilized to enhance decarbonization effects, while in the cost optimization scenario, SOFCs were leveraged to increase self-consumption, enabling the three-battery system to operate economically.

High-resolution interpolation method for building electricity profiles based on volatility quantification and pattern recognition

Yinao Zhou, Xuyuan Kang, Xiao Wang, Da Yan
Building Energy Research Center, School of Architecture, Tsinghua University, Beijing 100084, China

As the penetration rate of renewable energy in the power grid increases, it is essential to reduce energy consumption and carbon emissions in buildings. The interaction between building microgrid and power grid has gained significant research attention. However, most building energy data is collected at 1h intervals, which mismatches the 15min intervals used in power grid control and demand response. Existing highresolution interpolation methods for building electricity data cannot accurately capture the feature of daily peak and volatility. This study developed a high-resolution interpolation method for building electricity profiles using volatility quantification and pattern extraction method, depicting volatility and randomness at high temporal resolutions. Validation results of the proposed method on high-resolution electricity data of 19 commercial complexes in North and Northeast China was conducted, and the proposed method is more accurate than zero-order interpolation method regarding daily peak and volatility. Then, the proposed model was applied on one case of building microgrid optimal control, and the control performance is evaluated. Compared to the hourly data, the proposed model can evaluate operating cost and battery cycles more accurately, providing practical insights for building microgrid design optimization.

【HUMAN 03: Environmental Quality】

9th December, 3:15pm ~ 4:30pm

Session Chair: Jae-Weon Jeong, Hanyang University

Session Chair: Andrew Marian Zajch, Osaka University

A Study on Carbon Dioxide Emission Rates of Chinese University Students in Various Activities

Yanyan Li[1,2], Chenyang Jia[1,2], Zhen Sun[1,2], Siru Gao[1,2], Xue Wang[1,2], Yongchao Zhai[1,2]
[1]College of Architecture, Xi'an University of Architecture and Technology, Xi'an, China; [2]State Key Laboratory of Green Building, Xi'an University of Architecture and Technology,, China

When using CO2 as a tracer gas to evaluate building ventilation rates, the CO2 emission rate of occupants is a key parameter. This study measured the CO2 emission rates of 60 young Chinese university students during various office and walking activities using a respiratory-metabolic testing system. The results showed significant gender differences in CO2 generation rates, with body weight and body surface area being the main factors influencing individual variability in CO2 emission rates. The Equation provided in ASTM D6245-18 for estimating CO2 emission rates significantly underestimates the CO2 generation for young Chinese populations. Based on experimental results, this paper proposes correction factors for the prediction equation: 1.2 for males and 1.4 for females. Lastly, the paper reexamines the confusing concepts in constructing the ASTM prediction equation and offers suggestions for its revision.

Determination of inhaled carbon dioxide concentration using preprocessed-steady-state analysis with computer-simulated persons

Ryu Itokazu[1], Kazuki Kuga[2], Kazuhide Ito[2]
[1]Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan; [2]Faculty of Engineering Sciences, Kyushu University, Japan

Carbon dioxide (CO2) concentration is used as an indicator for ventilation design and inhaled air quality, and CO2 is mainly generated by the continuous breathing of room occupants. Hence, it is important to predict and control not only the indoor CO2 concentration but also the inhaled CO2 concentration. Computational fluid dynamics (CFD) simulations with computer-simulated persons (CSPs) are appropriate methods with which to predict inhaled CO2 concentration values. However, to obtain accurate inhaled CO2 concentration measurements, we must continue the transient analysis reproducing the transient breathing cycle, including inhalation and exhalation, until the CO2 concentration distribution reaches a steady state. This method is unsuitable for practical ventilation design, owing to the significant amount of analysis time required. Therefore, this study proposes a new method for evaluating the inhaled CO2 concentration by using preprocessed-steady-state analyses to reduce the computational load while maintaining prediction accuracy. To demonstrate this method, we assumed an office room model with two CSPs under 60 m3/h supply displacement ventilation conditions. The preprocessed-steady-state analysis method was performed in three steps: 1) initial flow and temperature field analysis without breathing; 2) one transient breathing simulation with transient exhalation and 2s no breathing; 3) steady-state inhalation analysis with the CO2 source set based on the transient breathing analysis. In addition, we compared the inhaled CO2 concentration values obtained by using the full transient and preprocessed-steady-state analyses. The inhaled CO2 concentration value obtained via the preprocessed-steady-state analysis was reasonable, compared with the full transient analysis and

thereby confirmed its applicability to practical ventilation design.

Implementation of Real-Time Simulation of Infection Risk Using CO2 Sensors and Local Positioning Systems

Miguel Yamamoto, Akihiro Kawamura, Hisashi Hasebe
Shimizu Corporation, Japan

In the aftermath of the COVID-19 pandemic, there has been an increased focus on countermeasures against emerging infectious diseases. In view of this development, this study aimed to implement a system to simulate infection risks due to through the air transmission in real time. A method based on the Wells-Riley model was employed to predict the infection risk distribution due to airborne transmission/inhalation from CO2 concentrations, and due to direct deposition from occupant locations. A web application was developed to predict infection risk on the cloud, utilizing application programming interfaces (APIs) to interface with CO2 sensors and local positioning systems (LPS) via a building operating system (BOS). For verification, the system was employed in an office building to confirm the predicted infection risk. In terms of airborne transmission/inhalation, the model predicted a higher infection risk in areas with higher CO2 concentrations, which could be attributed to poorly ventilated spaces and periods. In terms of direct deposition, the model predicted a higher infection risk with no or insufficient social distancing among people, and a lower infection risk when social distancing was sufficient. The integrated infection risk distribution was similar to the combination of the infection risk distribution due to airborne transmission/inhalation and that due to direct deposition. Therefore, the proposed system was confirmed to reasonably predict the infection risk distribution. The system enables early detection of seats and areas with a high infection probability. This implies that the building manager can utilize the system as a reference for ventilation decisions, whereas in a hot desking office, occupants can utilize the system as a reference for selecting seats, thereby enabling infection control measures in accordance with the actual situation.

Simulation study on the performance enhancement of nanofiber air filters using bead-on-string structures

Junjie Liu[1], Jing Xu[1], Xin Zhang[1,2]
[1]Tianjin Key Lab of Indoor Air Environmental Quality Control, School of Environmental Science and Engineering, Tianjin University , China; [2]Energy Research Institute @ NTU, Nanyang Technological University Singapore, Singapore

Electrospun nanofiber filter media can achieve high particle capture efficiency and low airflow resistance through bead-on-string structures. This study simulates the impact of these structures on air filtration performance. The elliptical bead shape was applied to a virtual fiber model to assess the influence of bead volume fraction (BVF) on filtration performance. The simulation method was validated using real nanofiber media, with a BVF of 30% delivering the highest quality factor in this study. These findings provide valuable insights for improving bead-on-string structures in nanofiber air filters.

Effects of air barrier tables in restaurants dedicated to heated tobacco products

Yuan Hirayama, Sihwan Lee
Nagoya University, Japan

With the recent revision of Japan's Health Promotion Law, more restaurants now allow the use of heated cigarettes. Although these cigarettes are marketed as a safer alternative to traditional cigarettes, they still emit harmful substances. To address passive smoking in such environments, this study developed an air barrier table designed to reduce exposure to these substances. Through experimental measurements, the optimal air velocity of air barrier was determined to be 0.7 m/s. Using this data, computational fluid dynamics (CFD) analyses were conducted on both a human body model and restaurant models of varying sizes (small, medium, and large) to evaluate the air barrier's effectiveness. The experiments measured the attenuation of air velocity at various air barrier velocities, while the CFD analysis tracked the intake of nicotine and CO2. Results showed that the air barrier reduced nicotine intake 87.4% in the human model, and by 55.4%, 46.9%, and 38.6% in the small, medium, and large restaurant models, respectively. The variation in results between the models was likely due to difference in the turbulence model and ventilation systems (ceiling ventilation in the human model vs. kitchen ventilation in the restaurants models). Future research will further investigate the performance of air-barrier tablesin the restaurants models equipped with ceiling ventilation systems.

【SYSTEM 05: Daylight and Solar Shading】

9th December, 3:15pm ~ 4:30pm

Session Chair: Genku Kayo, Tokyo City University

Session Chair: Pengyuan Shen, Tsinghua University

Comparative analysis of haze and daylighting performance in aerogel glazing systems with varying structural parameters

Dongmei Zheng[1,2], Youming Chen[2], Da Yan[1]
[1]Building Energy Research Center, School of Architecture, Tsinghua University, Beijing, China; [2]College of Civil Engineering, Hunan University, Changsha, China

Aerogel glazing system (AGS) demonstrates significant energy-saving potential in buildings. Particle size and filling thickness are two critical structural parameters of AGS. However, the quantitative influence of particle size and filling thickness on the haze, daylighting performance, and discomfort glare of AGS have not been investigated. In this study, AGS with varying particle sizes (1 mm, 2.5 mm, 4 mm) and filling thicknesses (8 mm, 12 mm, 16 mm) are studied. Haze measurements were conducted using a spectrophotometer. The daylighting performance and discomfort glare of AGS were assessed through simulation utilizing the three-phase method in Radiance software. Besides, the influence of room depth and daylight climate zones on the daylighting performance and discomfort glare of AGS were discussed. The results showed that smaller particle sizes and greater filling thicknesses enhance haze but reduce discomfort glare, and improve daylighting performance at the front of the room but diminish it at the rear. Furthermore, daylight climate zones significantly impact the trends of spatial daylighting performance related to particle size and filling thickness, while exerting minimal influence on the trends in spatial discomfort glare.

Research on daylighting regulation mechanism in sunken underground space based on prismatic glazing and architectural spatial form

Gerui Sui[1], Jiawei Leng[1,2], Xiaohan Shen[1]
[1]School of Architecture, Southeast University, Nanjing, China; [2]Nanjing Urban Planning & Design Institute of Southeast University, Nanjing, China

With the rapid development and utilization of underground spaces in China, the improvement of its internal environmental quality is becoming a challenging task. Compared to other physical environmental elements, limited natural light is the main characteristic that distinguishes built environments above and below ground. At present, most of the research focuses on parameter optimization using architectural spatial form to realize passive daylighting regulation in underground spaces. However, few studies are focusing on advanced daylighting systems, especially complex fenestration systems, which are not conducive to maximizing the rights to daylight in underground space. Based on the combination of spatial form and prismatic glazing, this paper studies the collaborative regulation mechanism of daylighting effect in sunken underground spaces in one hot summer and cold winter area of China (Nanjing), with coupling impact of daylighting on thermal comfort and energy consumption considered. The findings reveal that indoor net height and the volume of sunken space are the key spatial form variables. Key variables for the selected prism would be mainly influenced by the orientation. The regulation amplitude of the prism is also affected by the length of the opening side and the length difference of the two opening sides. A reasonable prism design could enhance the overall daylighting capacity of the

space without affecting thermal comfort and energy consumption. This study is expected to provide theoretical support for the early design stage of underground spaces, thereby promoting the sustainable development of future cities.

Validation of Melanopic Equivalent Daylight Illuminance in a Test Chamber: Comparison of Selected Spectral Simulation Tools in Various Lighting Scenarios

Tiara Nurhuda[1,2], Gontar Amin[1], Rizki A Mangkuto[1], Joko Sarwono[1], R Revantino[3]
[1]Department of Engineering Physics, Institut Teknologi Bandung, Indonesia; [2]Department of Industrial Engineering, Universitas Insan Cendekia Mandiri, Indonesia; [3]Center of Industrial Standardization and Services for Material and Technical Product Ministry of Industry the Republic of Indonesia

The non-visual response triggered by melanopsin photoreceptors is a key factor in the development of optimal lighting designs for built environments. Lighting simulations are often used to compare design options and optimize lighting conditions in various spaces. However, to account for complex non-visual responses, simulation tools must be able to integrate the spectral composition of light and materials. Therefore, this study aims to validate two spectral simulation tools, namely ALFA and Lark v.3, by comparing their predicted values of melanopic spectral (380-780 nm) and mel-EDI. For the measurement, a physical model was constructed using a 0.9 m × 0.9 m × 1 m multiblock wooden material. The interior of the test chamber was lined with interchangeable plywood in black, white, yellow, and blue colors. A tunable luminaire was installed in the center of the ceiling, with the Color Correlated Temperature (CCT) value of the luminaire adjustable in variations of 3000 K, 4000 K, 5000 K, and 6000 K. Overall, ALFA is more accurate for simulating broad-spectrum reflections in highly reflective environments, while Lark excels in simpler, selective-reflectance scenarios with faster simulations, making each tool suited to different lighting design needs.

Exergy Analysis of PV-Based Electric Lighting

Umi Nasrah Binti Hashbullah, Genku Kayo
Tokyo City University, Japan

Most countries nowadays discuss and implement policies toward achieving a carbon-neutral society. It is undeniable that solar energy is one of the renewable resources and is a major driver in climate change policies. Therefore, Photovoltaic (PV) panels have become an essential technology for electricity production. However, it is hard to find a discussion of the exergy consumption of electric light that is used 100% source from PV Solar panels. Exergy analysis helps identify where improvements can be made to increase the lighting system's overall efficiency and exergy utilization. This paper aims to describe the exergy process of PV-based electric lighting and calculate the exergy consumption using the exergy balance equation. The results compared the Exergy Consumption, between Summer and Winter at Yokohama and Summer (June) between Yokohama and Kuala Lumpur. Generally, the results show that the PV Panel performance of Exergy Consumption, is 72.93% while Electricity Exergy, is 22.22% and the balance of 4.85% is for Light Exergy, . It can be concluded that most of the Exergy is consumed and just a small amount will be used for electricity and light production.

Evaluation of the solar shading of various combinations of shading materials and blinds

Funa Shibahara[1], Kozo Takase[1], Tatsuhiko Nakao[1], Nozomu Yoshizawa[1], Koichiro Saito[2], Makoto Satoh[3], Yoshihiko Akamine[4], Sigeki Nishizawa[4], Keiichiro Taniguchi[5], Masato Miyata[4]
[1]Tokyo University of Science, Japan; [2]YKK AP Inc; [3]Satoh Energy Research; [4]National Institute for Land and Infrastructure Management, MLIT; [5]The University of Tokyo

The solar radiation shading performance when various exterior shadings, glazing, frame, and interior shadings are combined have not been evaluated appropriately in the Building Energy Standard in Japan. The purpose of this study is to establish the method for evaluating the solar radiation performance by conducting experiments and simulation under various shading and blind combinations. In this study, the solar heat gain coefficient (SHGC) was defined as the ratio of the amount of heat due to solar radiation reaching the room to the amount of solar radiation outdoors before passing through external shadings. The SHGC was measured using the measuring device which is surrounded by five heat flow sensors and detect the amount of heat transfer and solar gain through fenestration. Accuracy verification of simulation was performed using Rhinoceros and HoneybeePlus version 0.0.06 which uses Radiance version 5.1. In this verification, the evaluation surface was placed in the same position as the measuring device, and the amount of solar radiation on each evaluation surface was used to calculate the SHGC. The consistency between the experimental results and the simulation was verified. It was shown that the experimental results could be reproduced.

【SYSTEM 06: Radiation】

9th December, 3:15pm ~ 4:30pm

Session Chair: Makiko Ukai, Nagoya University

Session Chair: Xiaolei Yuan, Aalto University

Modeling and validation of dynamic solar radiation and heat transport based on spectrally selective composite ice structures

Yuanyuan Zhang[1,2], Jing Liu[1,2], Yun Xia[3], Yue Wu[4], Zhen Wang[5]
[1]School of Architecture and Design, Harbin Institute of Technology, Harbin, PR China; [2]Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, PR China; [3]Heilongjiang Province Academy of Cold Area Building Research, Harbin, PR China; [4]School of Civil Engineering, Harbin Institute of Technology, Harbin, , PR China; [5]Hong Kong Polytechnic University, Hong Kong, SAR China;

Composite ice shell buildings are representative projects in the ice and snow tourism industry in cold and severe cold regions, with great economic values. Composite ice used in constructing shell structures for composite ice shell buildings is formed by freezing water with the addition of reinforcing materials and approximately has 4 and 3 times the shear strength and tensile strength, respectively, compared to pure ice. The excellent mechanical performance of composite ice facilitates innovation and development in the design and functionality of ice buildings. However, the enhanced scattering effect brought by the reinforcing materials results in higher spectral absorptivity of composite ice than that of pure ice, which increases the temperature sensitivity of the structure. This heightened sensitivity necessitates careful thermal management to ensure structural stability and longevity, especially under varying meteorological conditions. Based on the previously obtained radiation spectrum of composite ice, this study established a dynamic solar radiation and heat transfer model for composite ice structures. The model was validated using temperature data from field experiments on composite ice structures, showing good agreement between the simulation results and the experimental data. Furthermore, the model was extended to reveal the temperature distribution on the surface of composite ice structures with varying reinforcing materials content. In summary, the model can accurately simulate the dynamic solar radiation and heat transfer in spectrally selective composite ice structures in real-time and predict the temperature field of composite ice shell structures, thus, providing important references for the design, operation, and maintenance of composite ice shell buildings.

The thermal performance of a novel convection-radiation coupled liftable Workstation Terminal

Shiying Li[1,2], Yifan Wu[1,2], Borong Lin[1,2], Yihui Li[1,2]
[1]Department of Building Science, Tsinghua University, Beijing 100084, China; [2]Key Laboratory of Eco Planning and Green Building, Ministry of Education, Tsinghua University, Beijing, China

Energy conservation in the construction sector is essential for achieving China's carbon peak and neutrality goals. Given the challenge of balancing energy savings and comfort in existing office buildings, a novel convection-radiation coupled liftable Workstation Terminal is proposed. Through the design of convection-radiation coupling, the local environment at the personal scale is optimized, and adjustable operation based on it meets the rapid and comfortable intermittent energy demand of personnel. The liftable design of the workstation panel offers users a new healthy office mode of alternating between standing and sitting. Based on this, a new type of Workstation Terminal experimental platform is built,

and experiments are conducted to obtain its thermal performance. The main conclusions are as follows. First, the local environmental creation was optimized. In the heating mode, heating ranges were focused on the personnel area below the desktop. Temperatures of sedentary workers' ankles in the radiation mode were 0.6°C greater than their head temperatures. In the cooling mode, the design of a convective air supply on the desktop can cool the head of personnel, and the head temperature was 1℃ lower than the ankle. Moreover, the liftable workstation panel design provided a new healthy office mode of alternating between standing and sitting, and the convection-radiation coupling structure design can meet the environmental creation requirements for standing office in winter. Furthermore, the combination of convection followed by radiation improved the intermittent operation capability of the terminal. In comparison to employing a radiation panel, the thermal response speed during the start-up phase was 4.2 times faster, and the radiation heat transfer ratio during the stable phase was 5.7 times higher than during the start-up phase. Lastly, the workstation terminal can expand the winter background temperature from 20℃ to 17℃, indicating flexible energy-saving potential.

Performance Evaluation and Optimisation of a Building Integrated Transpired Solar Collector and Phase Change Material Storage System

Shengteng Li, Zhenjun Ma
University of Wollongong, Australia

The urgent need to reduce energy consumption in the building sector has driven the integration of renewable technologies to improve sustainability and environmental impact. Transpired solar collectors (TSCs) are a cost-effective and efficient technology for space heating through fresh air intake. Phase change materials (PCMs), known for their latent heat storage capabilities, have been widely studied in various applications. This research examined the thermal performance of a building-integrated TSC and PCM system, aiming to extend effective heating supply times and optimise the system’s design parameters. Using the finite difference method and considering energy, mass balance, and an enhanced enthalpy method, 32 simulation cases were conducted based on orthogonal tests. These simulations varied the operating conditions of the TSC and the properties of the PCM. A multivariate analysis was then performed to identify the optimal design. The findings reveal that the suction flow rate on the external wall was the most influential factor in improving indoor thermal performance, followed by the PCM location. The optimal TSC-PCM system achieved a thermal efficiency of 401.8% and an exergy efficiency improvement of 26.9% compared to a TSC-only system over a seven-day period. Additionally, the system reduced heat pump energy consumption by an average of 16.1% compared to the TSC-only system, and 31.1% compared to the baseline, over the same period.

Evaluation of Spatial Distribution of UV Irradiance for Upper-room UVGI by Simulation and Measurements

Chunxiao SU
University of Shanghai for Science and Technology, China, People's Republic of

In this study, a mathematical model of the irradiance distribution of ultraviolet double lamps was established for the single lamp and the UV irradiance of 50cm, 100cm, 150cm and 200cm typical planes of ultraviolet single and double lamps was numerically simulated and experimentally measured. The measured inhomogeneity coefficient of the UV lamp was higher than the coefficient obtained by the simulated radiation, but the decrease trend of the uneven coefficient in 50cm, 100cm, 150cm and 200cm is consistent. The degree of decline in the inhomogeneous coefficient in the 50cm and 100cm planes was higher than that of the 150cm and 200cm planes. The measured results of the established

UV double lamp model were consistent with the results of the mathematical model. With the increase of the typical plane distance, the measurement was higher than the simulation result, the inhomogeneous coefficient gradually approaches 1, and the irradiance distribution is uniform.

Thermal Environment Analysis for Large-Scale Indoor Spaces Using Radiant Panel Heating-Cooling System

Wei Jing, Akihito Ozaki, Younhee Choi, Yusuke Arima, Sungjun Yoo
Kyushu University, Japan

This study aims to develop a numerical simulation method and to improve its calculation accuracy to evaluate the thermal environment quantitatively, supporting the environmental design for large-scale indoor spaces equipped with radiant panel heating-cooling system (RPHCS). We conducted an experimental investigation of the thermal environment in a research institute with large-scale indoor spaces equipped with RPHCS in both summer and winter. Measurement results, including the vertical air temperature and humidity, surface temperatures of walls, and temperatures related to the radiant panels have been analyzed. Based on the experimental conditions, the study also performed a numerical simulation of the indoor thermal environment using the BES (Building Energy Simulation) method. We used measurement data to estimate the convective heat transfer coefficient for the non-standard radiant panels as input condition. The temperature gradient in vertical direction was calculated by ways of dividing spaces and considering imaginary ceilings and walls. The simulation results showed good consistency with the experimental data and the appropriateness of this method has been confirmed.

Tuesday, 10th December

Tuesday, 10th December, 10:45am ~ 12:00pm

【DESIGN 07: CFD and Airflow】

10th December, 10:45am ~ 12:00pm

Session Chair: Satoru Iizuka, Nagoya University

Session Chair: Jiefan Gu, Tongji University

CFD-EnKF Simulation of Indoor Temperature and Humidity Field Driven by Finite Monitoring Data

Weixin Qian[1,2], Jing Liu[1,2]
[1]School of Architecture and Design, Harbin Institute of Technology, Harbin, China; [2]Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin, China

This study investigates the implementation of a dry mist evaporative cooling system in a semi-outdoor area on the campus of the Singapore University of Technology and Design, specifically a space outside a lecture theatre designed for cross ventilation. Singapore's hot and humid climate, combined with good natural ventilation at the chosen site, provides an opportunity to explore evaporative cooling despite challenges posed by high relative humidity. The study focuses on optimizing dry mist deployment through computational fluid dynamics (CFD) simulations, with the aim of enhancing thermal comfort without the use of additional fans. A mesh sensitivity study was conducted to determine the optimal computational grid for the simulation, and natural ventilation was studied using prevailing wind directions from the north and south. Wing walls were introduced to redirect wind towards areas where airflow was obstructed, improving natural ventilation in stagnant zones. The core of the study explores the effects of dry mist deployment under various configurations. Simulations showed that lower wind velocities allowed the cool air from misting to settle more effectively, while high wind velocities rapidly replenished the ambient air, limiting cooling effectiveness. The study concluded that using multiple nozzles with lower mass flow rates was more effective than single high-flow nozzles, as this configuration better distributed the cooled air across the site. Additionally, strategically placed wing walls enhanced the system's performance by directing wind to key areas. The results offer practical insights into the deployment of dry mist systems in semi-outdoor spaces in tropical climates, optimizing both thermal comfort and water usage.

Development of dynamic coupling simulation method between CFD and building energy simulation for indoor thermal analysis involving PCMs

Tianxing Zhang[1], Haruka Kitagawa[2], Takashi Asawa[1]
[1]School of Environment and Society, Tokyo Institute of Technology, Japan; [2]Institute of Technology Center for Energy Engineering, Shimizu Corporation, Japan

Due to the demand to reduce building cooling energy consumption, phase change materials (PCMs) are recommended for passive radiant cooling. Computational fluid dynamics (CFD) has been widely applied for simulating indoor air temperature to evaluate the cooling effect of PCMs. To further improve the accuracy of indoor air simulation, building energy simulation (BES) was coupled to provide boundary conditions for CFD. However, the previous coupling simulation method tended to simplify the property

input of PCMs in CFD and cannot calculate the thermal hysteresis of PCMs. This study developed a dynamic coupling simulation method between CFD (Ansys Fluent) and BES (EnergyPlus) based on the original external and quasi-dynamic coupling methods. BES was responsible for building components and CFD for airflow. The method was validated for an experimental building with the radiant floor cooling system in Tangerang, Indonesia, which equipped a radiant floor cooling system containing forced nocturnal ventilation in the underfloor space and increased thermal mass with PCMs. Three popular turbulent models in the Reynolds-Averaged Navier-Stokes (RANS) equation for CFD, the Re-Normalization Group (RNG) k-ε, Realizable k-ε, and Shear-Stress Transport (SST) k-ω models were compared. The result showed that the SST k-ω was the most accurate for the PCM temperature (R^2=0.984, RMSE=0.4 ℃) and indoor air temperature (R^2=0.986, RMSE=0.5 ℃). This validation demonstrated that the developed dynamic coupling simulation method can perform effectively in indoor thermal analysis involving PCM-based constructions.

Field Measurement and CFD Analysis on the Effects of Street Trees on the Thermal Environment in the Central Business District of Tokyo

Shanshan Liu[1], Takashi Asawa[1], Keigo Hamada[2]
[1]Tokyo Institute of Technology, Japan; [2]Nikken Sekkei, Japan

In urban areas, street trees are commonly employed to modulate outdoor microclimates through their shading capabilities. However, the presence of trees also causes stagnant wind velocity, potentially worsening the wind environment at the pedestrian level during hot seasons. Especially in the Central Business District (CBD) area, the extensive shading provided by high-rise buildings may cover the shading provided by street trees, and the declined wind velocity caused by trees may negatively impact outdoor thermal comfort. It is important to investigate the trade-off relation of microclimate improvements between building shades, tree shade, and wind stagnation by trees clearly. In this study, a typical CBD area in Tokyo, Japan, where the road direction is north-south and consists of three blocks of high-rise buildings and street trees, was selected for field measurement and simulation. The shading effects of buildings and trees and the wind stagnation effect of trees were evaluated by a moving observation and Computational Fluid Dynamics (CFD) model in a representative sunny summer day. Sky View Factor (SVF), tree view factor (TVF), building view factor (BVF) were utilized to quantify the morphological characteristics of the street, trees, and buildings. The thermal radiation environment and the wind environment were evaluated by the mean radiation temperature (MRT) and the wind velocity, respectively. The results showed that the super-high-rise buildings created huge shades and weakened the shading effect of trees. Furthermore, TVF and BVF were strongly correlated with wind velocity reduction. Finally, two scenarios of CBD area with and without street trees were analyzed for discussing the microclimatic benefits and trade-off relations of trees in the CBD area, and reasonable tree planting method were suggested. Overall, this paper demonstrated that tree planting in CBD area is not always effective and should be adapted considering the morphological characteristic of streets with trees and buildings.

A Comprehensive Analysis of Pedestrian Health Risks in Urban Street Canyons: Integrating Computational Fluid Dynamics and Multifactor Approaches

Xu Li[1], Xue Zhou[1], Lina Yang[2], Tiantian Xu[1], Jizhou Liu[1], Jiying Liu[1]
[1]School of Thermal Engineering, Shandong Jianzhu University, China; [2]BinZhou Polytechnic, China

In urban environments, pedestrian health is affected by both temperature and pollutants during commuting, and the shape of urban structures and afforestation can mitigate these health risks. Computational fluid dynamics (CFD) was used to establish a method considering different aspect ratios (building height/street width, AR = H/W =0.75, 1, 1.25, 1.5, W = 20 m) and leaf area density (LAD) were used to obtain the distribution of pollutant concentration and temperature in the street canyon. Meanwhile, comprehensive environmental quality index for thermal pollution (EQI) was introduced to better evaluate the health risk to pedestrians under the coupling of the two. In order to study the effects of local solar time (LST), LAD, and AR on the EQI distribution individually or jointly, multivariate analysis of variance (multivariate ANOVA) was used to evaluate the interaction between the factors. The results show that the larger the LAD, the larger the EQI, and the more suitable for pedestrian activities. When LST is 12, the EQI value is the lowest, and the maximum EQI interpolation can reach 2.6. The influence of AR on EQI distribution is not high and has no statistical significance, while LAD and LST together have an impact on EQI.

【DESIGN 08: Heat and Moisture】

10th December, 10:45am ~ 12:00pm

Session Chair: Jing Liu, Harbin Institute of Technology

Session Chair: Marcel Ignatius, National University of Singapore

Co-simulation on the combined indoor heat and moisture control of the composite TABS with absorbent material

Xiaochen Yang, Yixuan Jiang, Zhe Tian, Ruizhi Wang
Tianjin Key Laboratory of Built Environment and Energy Application, School of Environmental Science and Engineering, Tianjin University, China, People's Republic of

The Thermally Activated Building System (TABS) is proposed to reduce building energy consumption. TABS can use natural cold and heat sources to form a thermal barrier, which can hinder heat transfer in the building envelope and control the load of building envelope by adjusting the temperature difference between the indoor environment and the thermal barrier plane. The energy supply of TABS is mainly radiation, but the use of radiant cooling systems in humid regions is limited by surface condensation. The composite envelope with porous absorbent material coupled with TABS structure can realize dual-effect regulation of indoor temperature and humidity, and avoid surface condensation under cooling condition of TABS envelope. The heat and moisture transfer inside the composite envelope is more complex than that of a single TABS structure or porous absorbent material, which deserves more in-depth research.
Based on the effective moisture penetration depth model, co-simulation of an environmental chamber located in Tianjin was carried out in EnergyPlus and Dymola. The model was validated by experiments conducted in the environmental chamber. Then optimized the system by simulating the heat and humidity regulation performance of the environmental chamber under different pipe water temperature, pipe diameter and porous absorbent material types. Finally, the performance of the composite structure was reflected by simulating and comparing the operating temperature, cooling load and building thermal resilience of the composite structure and TABS structure considering the outdoor climate.

Evaluation of regional condensation and mold growth risk in mass timber envelope using domestic CLT

Ji Hun Park, Sungwoong Yang, Seong Taek Kang, Sumin Kim
Department of Architecture and Architectural Engineering, Yonsei University, Seoul 03722, Republic of Korea

The 2015 Paris Agreement has catalyzed efforts to decarbonize the building sector, highlighting the need to address both operational and embodied carbon emissions. Wood-based construction, with its inherent carbon sequestration properties, presents a sustainable alternative to traditional materials. This study examines the hygrothermal performance of wall assemblies utilizing Korean ply-lam Cross-Laminated Timber (CLT) in the context of South Korea's diverse climatic conditions. While South Korea is advancing its regulations to support mid- and high-rise timber buildings, it lacks comprehensive design guidelines tailored to local environmental conditions, which contrasts with the established standards in North America. The research involves analyzing various wall assemblies based on international standards, specifically Canada's NECB, and adapting these to South Korea's climate. The study evaluates the effectiveness of these assemblies in mitigating condensation and mold risks through WUFI

simulations, incorporating data from seven representative Korean regions. Key findings indicate that while conventional wall assemblies generally meet acceptable mold growth rate (MGR) and mold index (MI) levels across all regions, the Korean ply-lam CLT assemblies show variability. Notably, high MGR and MI levels were observed in Incheon due to reverse condensation linked to high humidity and low temperatures. The results suggest that while conventional NECB-based CLT assemblies perform well in South Korea's climate zones, Korean ply-lam CLT requires specific design adaptations to address localized moisture-related issues. The study emphasizes the need for tailored envelope solutions to enhance the performance of timber buildings, ensuring they meet energy efficiency standards and are resilient to the unique climatic challenges of South Korea. This research contributes to the development of effective, climate-responsive timber construction practices, supporting South Korea's transition towards sustainable building practices and Zero Energy Buildings (ZEBs).

Analysis of Moisture Absorption and Desorption Phenomena on Building Materials Considering a Detailed Solar Radiation Model in Indoor Surfaces

Myonghyang Lee[1], Akihito Ozaki[2], Yusuke Arima[2]
[1]Ritsumeikan University, Japan; [2]Kyusyu University, Japan

Most thermal environment and heat load simulation software for whole building commonly simplify heat transfer calculations by using equivalent outdoor air temperature, overall heat transfer coefficient, and solar radiation shielding coefficient. These models assume that solar radiation entering the room is uniformly distributed across all interior surfaces, ignoring the differences between sunlit and shaded areas, and do not account for moisture transfer. This assumption can lead to discrepancies in how solar radiation is distributed on indoor surfaces. To accurately account for moisture absorption and desorption, as well as variations in indoor temperature and humidity, it is crucial to distinguish between sunlit and shaded surfaces through detailed numerical analysis. This study investigated how considering sunlit versus shaded surfaces affects building thermal environment analysis. This study conducted a model box experiment using a solar radiation device with variable irradiation. This setup allowed for a thorough investigation of moisture phenomena and the effects of sunlit versus shaded surfaces. The calculation accuracy of the simulation software THERB for HAM, which can predict in detail sunlit and shaded surfaces and moisture calculation of building materials, was also verified. Solar radiation was applied to either the entire floor or specific portions, and the impact of varying radiation levels on moisture absorption and desorption from humidity control materials was evaluated. Contrarily, shaded surfaces can exhibit hygroscopic phenomena even during irradiation. The effects of moisture absorption and desorption related to solar heat, air temperature, and humidity can be better understood by model box experiment and numerical simulation. It also examined how modeling these surfaces calculation point in detail influences the moisture absorption and desorption of the building material and the indoor temperature and humidity.

Evaluation of moisture effects on urban building energy performance in different climate zones of China

Xiaoyu Wang[1,2], Pengyu Jie[1,2], Xing Shi[1,2]
[1]College of Architecture and Urban Planning, Tongji University, Shanghai, PR China.; [2]Key Laboratory of Ecology and Energy-saving Study of Dense Habitat, Ministry of Education, Shanghai, PR China.

To address the limitations of existing urban building energy modeling (UBEM), which often neglects the effects of moisture, we developed an urban whole-building heat and moisture transfer (HAMT) model that accounts for wind-driven rain. The proposed model was validated by real urban building case,

using WUFI-Plus as the benchmark. This HAMT model was then applied to a real urban building case study to evaluate the impact of moisture on annual energy consumption predictions across three cities: Shanghai, Chengdu, and Changsha. The results showed a great agreement between the proposed model and WUFI-Plus. In Shanghai, when accounting for moisture, the annual heating load intensity increased by 6.06%, while the cooling load intensity rose by 22.11%, including 5.92% latent load. This led to a 19.73% overall increase in annual load intensity. In Chengdu, the total heating and cooling loads increased by 5.4% and 27.87%, respectively, resulting in a 24.36% rise in annual energy loads. Similarly, in Changsha, heating and cooling loads increased by 4.85% and 16.49%, respectively, leading to a 14.82% increase in total load. These findings underscore the critical importance of incorporating moisture effects into urban building load calculation models, particularly in regions with humid climates, such as those characterized by hot summers and either cold or mild winters in China.

Modeling and numerical simulation of Coupled Heat, Moisture and Salt Transport in porous building materials

yu zhang[1], Qinglin Meng[2], Junsong Wang[2], Chuanrui Li[2], Peng Ren[2]
[1]School of Architecture and Urban Planning, Key Laboratory of New Technology for Construction of Cities in Mountain Area, Chongqing University, Chongqing, China; [2]School of Architecture, State Key Laboratory of Subtropical Building Science, South China University of Technology, Guangzhou, China

Coastal buildings are subjected to both conventional hygrothermal stresses from the mainland and the corrosive effects of salt fog. A primary mitigation strategy is to enhance the inherent properties of the building envelope to resist salt fog damage. Understanding the heat and mass transfer mechanisms within the envelope is essential for designing durable structures that can withstand both thermal and moisture loads. Coupled heat, moisture, and salt transfer models are fundamental for elucidating these mechanisms in salt-contaminated porous materials. However, existing coupled heat, moisture, and salt transfer models are primarily theoretical and lack experimental validation, necessitating further research to bridge the gap between theory and practice. This study proposes coupled heat, moisture, and salt transfer model based on the conservation laws of moisture mass, energy, and salt mass. Numerical simulations and wind tunnel experiments are conducted to validate the proposed model.

【DIGITAL 04: Advanced Modeling】

10th December, 10:45am ~ 12:00pm

Session Chair: Hideaki Uchida, Osaka University

Session Chair: Xiaoyang Lv, South China University of Technology

Second-by-second data measurement, analysis and modeling for fan transient elucidation

Tatsu Kishida[1], Shohei Miyata[2], Minoru Matsuo[3], Kazuki Yajima[4], Yasunori Akashi[2]
[1]Taikisha Ltd., Japan; [2]The University of Tokyo, Japan; [3]Mitsubishi Heavy Industries Thermal Systems, Ltd., Japan; [4]SHINRYO CORPORATION, Japan

Dynamic characteristics need to be reproduced in HVAC (heating, ventilating and air-conditioning) system simulations for more detailed behavior utilization and optimal operation in future digital twin and smart buildings. The ability to accurately calculate the behavior of short time intervals is expected to provide new value in HVAC systems through applications such as frequency regulation service (FRS). However, most conventional simulations assume steady-state conditions, and few consider the dynamic characteristics of transient conditions. Therefore, in this paper, as a first step toward dynamic HVAC system simulation, we aimed to elucidate the dynamic characteristics of the fan and the variable-frequency drive, which are the key components of HVAC systems. We measured data in transient conditions during startup and shutdown and when the operating frequency is changed by the variable-frequency drive. The measured data were taken at 1-second intervals. As a result of analyzing the dynamic characteristics of the airflow rate with respect to frequency, a deviation due to the time delay between the frequency change and the actual change in airflow was observed, and the time delay was calculated to be 0.858 seconds based on the deviation width. In addition, due to the effect of the delay of the rotation speed relative to the synchronous speed (slip) of the three-phase cage-type induction motor used for the fan, the transient data for airflow with respect to power consumption deviated from the stability curve toward a higher power consumption during acceleration and toward a lower power consumption during deceleration. The transient characteristics obtained have many features that have been ignored in conventional static simulations. Then, the existing library in Modelica was modified based on these results to compare the simulation results. Reflecting these transient characteristics will improve the accuracy of the model and may contribute to the development of various applications such as FRS.

An IoT-Based Diagnostic Interaction System for HVAC performance in Office Buildings

Yutong Chen1, Daisuke Sumiyoshi2, Takahiro Yamamoto3, Takahiro Ueno4, Jewon Oh5
[1]Kyushu University, Graduate School of Human-Environment Studies, Japan; [2]Kyushu University, Faculty of Human-Environment Studies, Japan; [3]Kagawa University, Faculty of Engineering and Design, Japan; [4]The University of Kitakyushu, Faculty of Environmental Engineering Department of Architecture, Japan; [5]Sojo University, Faculty of Engineering Department of Architecture, Japan

HVAC systems have a significant impact on building energy consumption, especially when malfunctioning. In recent years, data-driven fault diagnosis models have attracted considerable interest from researchers. By placing numerous sensors in various modules of air conditioning (AC) systems and analyzing their performance under different operating modes, machine learning models can be constructed for accurate fault diagnosis and classification. However, these studies are often limited by dataset constraints, leading to inconsistent classification performance across different HVAC systems and buildings. Furthermore, the extensive sensor installation and analysis required may not be practical for real-world

building applications. The efficiency of an air-conditioning system is one of the important factors in evaluating a building's energy performance. Therefore, developing a simple and effective measuring device for rapid energy efficiency monitoring of air conditioners is crucial. To address this need, this study develops a cost-effective IoT (Internet of Things) device for real-time energy efficiency assessment. This study proposes an IoT-based BI-Tech (Behavioral Insight X Technology) system that utilizes the ESP12-F & ESP32S3 microcontrollers, integrating temperature, humidity, air velocity and current sensors. By employing advanced data analytics, the system provides actionable insights by calculating the HVAC system's capacity in real-time and delivering feedback to occupants through an intuitive iOS app. The AC monitoring system introduced in this paper is part of this overall system. It actively monitors key indoor parameters, HVAC air outlet data, and energy consumption.

Application of a Bayesian calibration method on an archetype of the building stock energy model using national open-access data

Xukang Zhang, Yohei Yamaguchi, Hideaki Uchida, Yoshiyuki Shimoda
Graduate School of Engineering, Osaka University, Japan

Building Stock Energy Model (BSEM) is an emerging tool that provides valuable insights for building designers, urban planners, and policymakers regarding energy efficiency and decarbonization strategies at city or country scales. However, existing models often encounter challenges in accurately predicting real-world phenomena. The Bayesian calibration (BC) method is a potential approach for incorporating uncertainties throughout the model construction process and has been successfully applied for individual building energy models and simplified stock energy models. Calibrating a national-level BSEM, however, presents additional challenges due to: 1) uncertainties in national open-access data because of the limited information, and 2) accumulated uncertainties of the use of meta models (prototype or archetype). Thus, applicability of established BC methods to a national BSEM remains a challenge. In this study, we applied an established BC method to calibrate an archetype of a national BSEM, using publicly available annual energy consumption data. The close alignment of the calibrated model with observed data demonstrates the effectiveness of our BC framework, indicating potential for broader application which could enhance accuracy in large-scale BSEMs.

Identifying suitable thermal response models for demand response management in multi-zone commercial buildings

Maomao Hu[1,2], Sally Benson[1], Jacques A. de Chalendar[1]
[1]Department of Energy Science & Engineering, Stanford University, Stanford, CA, 94305, USA; [2]Department of the Built Environment, College of Design and Engineering, National University of Singapore, Singapore

Forecasting building thermal dynamics is of great importance for building managers to implement demand response (DR) control strategies. In this study, we developed a series of grey-box Resistance-Capacitance (RC) models with varying complexities and used the Likelihood Ratio Test technique to identify the most suitable model. A commercial building in California with 217 zones was selected to test the proposed modeling and model selection method. We evaluated the candidate models using experimental data collected under different DR control strategies (i.e., indoor air temperature setpoint adjustments), and the 5R4C model was identified as the most suitable model using the Likelihood Ratio Test. The proposed grey-box models can utilize the operational data from smart sensors while incorporating the prior physical knowledge in the models, making them interpretable and trustworthy in practice. The 5R4C model is recommended as the benchmarking model for forecasting building thermal

behavior under different DR control strategies to enhance thermal comfort management.

Estimation of Multi-Layered Soil Thermal Properties using Data Assimilation Method

Yutaka Shoji[1], Takao Katsura[2]
[1]Kajima Technical Research Institute, Japan; [2]Hokkaido University

As global warming becomes a reality, the widespread adoption of shallow geothermal energy, known for its stability and ubiquity, is becoming increasingly important. The performance of shallow geothermal utilization depends heavily on soil thermal properties, such as the effective soil thermal conductivity and groundwater flow velocity. While methods for estimating effective soil thermal conductivity through thermal response tests are known, methods for estimating groundwater flow velocity have not been established. In this study, we propose a method to simultaneously estimate the vertical distribution of effective soil thermal conductivity, and the groundwater flow velocity by applying the Ensemble Kalman Filter (EnKF), a representative data assimilation method, to a ground heat exchanger model that considers multi-layered ground with groundwater flow. Numerical data assimilation experiment was performed on a quasi-3D borehole heat exchanger simulation with different soil effective thermal conductivities and groundwater flow velocities for each of three layers, using fluid temperature distributions in U-tubes as observed data. The results showed that the effective soil thermal conductivity and groundwater flow velocity can be estimated simultaneously by setting appropriate fluid heating conditions. This study proposed a method for estimating vertical thermophysical property distribution that takes into account the multi-layered nature of the ground. This method can be an important proposal to obtain more accurate simulation results for shallow geothermal applications in the presence of groundwater flow velocity.

【FUTURE 04: Urban-scale Simulation】

10th December, 10:45am ~ 12:00pm

Session Chair: Takashi Asawa, Institute of Science Tokyo

Session Chair: Jianli Chen, Tongji University

Reviewing global practices for a new framework of carbon neutral codes in developing countries

Suhaas Mathur[1], Vishal Garg[2], Jyotirmay Mathur[3]
[1]Woonerf Inc; [2]Plaksha University; [3]Malaviya National Institute of Technology

This paper presents a comprehensive review of the policy advancements for carbon neutrality in buildings and connects the dots with building energy simulation, post occupancy studies, and energy use benchmarking practices seen in early adopters such as the EU, USA, the UK, and Japan over the last 70 years. It is observed that regulating energy use in buildings by way of policy instruments has its roots in the energy security concerns in the 70s. Over time, global climate governance starting in early 2000s informed the evolution of those policies into their present form, with net-zero energy and emissions performance emerging as key to mitigate climate change. Building energy simulation, post occupancy evaluation, and energy-use benchmarking have been used in the development of policies with significant variations across countries. Researchers and practitioners strive to explain and reduce the gap between predicted and measured energy use via probabilistic approaches to prediction. Advanced technologies such as IoT, smart meters, digitization of building information, and capabilities such as machine learning and artificial intelligence are expanding the toolset for policy development and enforcement. They are also enabling research to reduce the gap between predicted and actual energy use. Distilling from the global practices from the last 70 years, the paper concludes with identifying the opportunity for developing nations to leapfrog to the development of carbon neutral building codes.

Generating Individual Trajectories for Synthetic Populations with a Large Language Model

Ryotaro Ohara, Hideaki Uchida, Yohei Yamaguchi, Shinya Yoshizawa, Katsuya Sakai, Yoshiyuki Shimoda
Graduate School of Engineering, Osaka University, Japan

Human mobility simulations can be applied in urban planning across various domains, such as the prediction of occupancy levels in buildings and the future charging demand of electric vehicles (EVs). However, accurately modeling individual mobility trajectories and travel demands at a high spatiotemporal resolution remains a challenge. In this study, a novel approach is proposed for simulating human behavior at an urban scale by representing mobility trajectories as character sequences and using language models. First, trajectory data collected from smartphones across Japan are processed and mapped onto a sequence of geographic spaces divided using grid codes. Each grid code is then assigned a certain character, enabling the representation of the trajectory of an individual as a character string. Subsequently, a large language model with GPT-2 architecture is trained from scratch on the character sequences to generate human mobility patterns. The model takes demographic attribute inputs, such as residential locations, and outputs a sequence of activities from the time an individual leaves home to the time they return. Highly realistic simulations of human mobility in urban areas can be achieved by coupling the model with synthetic population data. The model predicts the origin-destination (OD) patterns well, with a root mean square error (RMSE) value of 2.9%, compared with the travel survey data. The model also simulates the overall trends of time use and car usage, although gaps exist

between the model-generated results and ground truths. This approach has the potential to support decision-making in urban planning, including transportation planning and resource allocation, by providing accurate predictions of population dynamics.

A Study on Outlier Detection and Imputation Methods for Electricity Consumption Data of Buildings

Hitoshi Naruse[1], Motoi Yamaha[2]
[1]Toenec Corporation, Japan; [2]Chubu University, Japan

To improve building environmental and energy performance, commissioning and energy simulation using measured data are essential. However, data cleansing is crucial because measured data may contain missing values and outliers. This study proposes a method to automatically detect and impute outliers and missing values in building energy consumption data.

A time-series model was applied to real data from two facilities. The proposed outlier detection method combines threshold setting, ARIMA-based detection, and an existing method from an R programming language package. However, when this package was applied to building electricity consumption data with large outliers, it resulted in many false detections. To reduce false detections, we preprocessed the data using a threshold and set a new critical value for standardized statistics from the ARIMA residuals, considering outlier characteristics.

The critical value needs to be larger than existing values for building energy data with daily and seasonal fluctuations to reduce false detections. Determining the appropriate critical value from two real datasets could improve detection accuracy. While some detected outliers were incorrect, the method successfully identified clear outliers. We also looked at LSTM, a machine learning technique, but found that there were many parameters that needed to be set. We concluded that this method is effective, except in cases involving consecutive outliers or missing values.

ZEB Retrofit Planning Methodology for Existing Office Buildings Using Building Energy Simulation

Masato Miyata[1], Yasuhiro Miki[2], Shigeki Nishizawa[1]
[1]National Institute for Land and Infrastructure Management, Japan; [2]Building Research Institute

To achieve decarbonization, enhancing energy efficiency in existing buildings is crucial. Non-residential buildings often undergo equipment renewal (e.g., air conditioning and lighting) every 10-20 years, but these updates typically involve simple replacements rather than redesigns based on current conditions, missing significant energy and carbon savings potential. To solve this problem, the authors are developing technical guidelines and design support tools for energy-efficient retrofitting. This paper presents findings from a trial ZEB (Net Zero Energy Building) retrofit planning of an actual office building (total area: 13,467 m², built in 1978) to gain insights into retrofit design.

The study defines three retrofit levels and conducts quantitative examinations using a building energy simulation tool for assessing compliance with the Japanese Building Energy Code.
- Level 1 (Common equipment renewal) uses Japanese Building Design Standards, achieving a 10% energy reduction compared to the current situation with primary energy consumption of 2377.5 MJ/m².
- Level 2 (ZEB retrofit) aims for the ZEB Ready level by optimizing equipment capacity, etc. through technical studies using building energy simulations, reducing primary energy consumption to 517.5

MJ/m².
- Level 2+ includes the addition of 236 kW photovoltaic power, further reducing energy consumption to 349.6 MJ/m².

Cost-effectiveness analysis reveals significant differences: Level 2+ offers utility cost savings of 42.8 million yen/year and renovation costs of 614 million yen, with a payback period of 14.3 years from Level 1 to Level 2+.

The findings indicate that achieving ZEB is possible even for office buildings more than 40 years old. However, the long payback period for ZEB retrofitting suggests that additional benefits, such as improved indoor thermal environments, should be considered to promote such investments

A data-driven methodology for efficient block-scale building energy consumption calculation for residential areas in Nanjing, China

Xinkai Zhang[1,2], Xing Shi[1,2]
[1]College of Architecture and Urban Planning, Tongji University, Shanghai, China; [2]Key Laboratory of Ecology and Energy-Saving Study of Dense Habitat, Ministry of Education, Shanghai, China

This paper provided a methodology for developing data-driven surrogate models for calculating residential building energy consumption at block scale. The research involved: (1) collecting 289 residential block samples in Nanjing, (2) extracting 35 typical prototypes of residential blocks, (3) developing parametric design models from these prototypes and generating an extensive sample library, (4) simulating building energy performance and calculating critical morphological indicators for the generated samples, and (5) training surrogate models using BPNN and the data prepared. As a result, two surrogate models were developed. Compared to the EnergyPlus-based block building energy simulation method, the developed models demonstrated high accuracy, with average absolute relative errors less than 0.2% of the EnergyPlus outcomes. Notably, they achieved significant reductions in computational time compared to EnergyPlus, with one model reducing it by 99.8% and the other by 65.7%. The surrogate models can support energy-efficient urban design and optimization, by greatly reducing the computational burden of building energy simulations.

【HUMAN 04: Environmental Quality】 ROOM: OUN 7A

10th December, 10:45am ~ 12:00pm

Session Chair: Rizki Armanto Mangkuto, Institut Teknologi Bandung

Session Chair: Marco Savino Piscitelli, Politecnico di Torino

A Study on Optimization Countermeasures of Outdoor Spaces in Chinese Ancient Towns in Summer Based on Thermal Acceptability

Liyuan Yin[1,2], Yan Wang[1,3], Aya Hagishima[2], Qiwei Dong[1]
[1]School of Architecture, Tianjin Chengjian University, China; [2]Interdisciplinary Graduate School of Science Engineering (IGSES), Kyushu University, Japan; [3]Faculty of Environmental Engineering, The University of Kitakyushu, Japan

Historical ancient towns in China are facing the challenge of integrated development of culture and tourism, and the tourism industry has high sensitivity to the response of climate change, which requires proposing climate regulation strategies for tourism-based ancient towns in response to the thermal comfort of tourists, so as to optimize their environmental quality. Therefore, using a representative historical ancient town in China as a case study, this study collected thermal environmental data from 20 measurement points in four types of spaces in the ancient town in summer, and proposed the spatial creation strategies for the ancient town to meet people's comfort needs. Based on the descriptive statistical analysis of the measured and questionnaire data, ①firstly, we established the thermal acceptability evaluation models for locals and tourists by using linear fitting regression; ②secondly, we proposed four thermal environment optimization strategies by using Envi-met numerical simulation and compared their improvement effects; ③finally, based on the comprehensive evaluation results, we proposed the optimal environment creation countermeasures for public spaces. The results showed that the PET value at the highest acceptability rate of locals (30.99℃) was higher than that of tourists (30.61℃), and the PET range at 90% acceptability rate was shifted to the hot side relative to that of tourists, with an offset amount of 0.54℃. In addition, in the simulated optimization scenario, the temperature within the canopy coverage of the arbor decreased by 8.13°C to reach the acceptable PET range for 80% of the interviewees. Therefore, we conclude that local people are more accepting and adaptive to the environment in summer, and the arbor layout with small spacing and array pattern can minimize PET values and improve people's thermal comfort.

Sensing urban air pollution levels using a simple regime-switching Markov chain

Jiading Zhong, Jianlin Liu
College of Environmental Science and Engineering, Donghua University, China

Urbanization process has led to a trade-off between reduced commute time and increased exposure to air pollution sources. Real-time monitoring and risk assessment can be achieved by combining sensors with numerical simulations, and emerging data-driven models offer opportunities to minimize the computational burden of the numerical models. This study explores the use of a simple regime-switching Markov chain (CLF-MC) for fast simulation of wind-driven pollutant dispersion in cities. The CLF-MC model is trained and tested using a synthetic dataset obtained from large eddy simulation (LES). The LES model is validated against a benchmark wind tunnel test, and the results indicate strong correlation between the simulation and the experiment. Through a grid search, the optimal configuration of CLF-MC for the problem studied is found and recommended. With this configuration,

it is demonstrated that the CLF-MC can faithfully reproduce the cumulative distribution of air pollution levels at the target receptor site. In a hold-out test, where the release condition is a time-varying release strength, the CLF-MC shows improved prediction results compared to baseline models. Compared to LES, the simple CLF-MC model is 4.8×10^6 times faster. These findings provide scientific references for fast and accurate wind-driven pollutant dispersion simulation using a probabilistic modelling approach.

Development a method to predict the thermal environment and energy consumption of office a building using openstudio and ANN

Yoshito Takahashi[1], Ken Takahashi[2], Masato Sasaki[1], Ryozo Ooka[2]
[1]Nihon Sekkei, Inc., Japan; [2]The University of Tokyo, Japan

We have developed a method to predict the thermal environment and energy consumption of the 35th floor of an office building in Tokyo. To manage building energy, it is desirable to flexibly change air conditioning setpoints according to orientation characteristics and usage, rather than uniformly air-conditioning an entire floor. Furthermore, providing a variety of thermal environments for office workers and allowing them to freely choose their environment in free-address offices is expected to improve the comfort of office workers. The floor is equipped with a system that senses air temperature and the location of the worker. If an office worker prefers a warmer or cooler environment, they can receive recommended spatial information from their smartphone. In this report, we present a simulation model developed using Openstudio and an artificial neural network (ANN) for predicting air conditioning control values. The purpose of Openstudio model is to generate training data for the ANN. Therefore, the model does not fully replicate the air-conditioning system of a real building. Instead, it focuses on predicting air-conditioning cooling and heating load, electricity consumption and indoor environment using internal heat generation, weather conditions and air-conditioning set temperature as input parameters. The model was tuned using one year of building data and achieved sufficient accuracy for generating training data. The ANN uses a convolutional autoencoder to predict the required air conditioning control values from the current and desired future temperature distributions. The model predicts control values, taking into account the influence of adjacent spaces because the spatial temperature data as input is represented as two-dimensional arrays and processed by convolutional neural network. The trained ANN predicted the air-conditioning control values well when the control values were changed over large zoning than with small zoning.

Numerical Study of Respiratory Droplets/Droplet Nuclei Generation via a Coughing Event Using Eulerian Wall Film model and Lagrangian Discrete Phase Model

Kazuma Nita[1], Nguyen Dang Khoa[2], Kasuki Kuga[2], Kazuhide Ito[2]
[1]IGSES Kyushu University / Japan, Japan; [2]Faculty of Engineering Sciences, Kyushu University

Airborne transmission and resultant respiratory infection are mainly caused by exposure to virus-laden droplets/droplet nuclei generated in the respiratory tract because of coughing and/or speaking. Accurate prediction of the total amount of droplets/droplet nuclei generated is essential for infection control. Hotspots of viral replication in the respiratory tract are heterogeneously distributed, so that the viral concentration—for example, RNA copies/mL—in droplets/droplet nuclei majorly depends on the generation site and mechanism. Key factors associated with the physical mechanism of droplet/droplet nucleus formation in the respiratory tract include: (i) thin film cleavage associated with bronchoconstriction, (ii) mucus detachment in the laryngeal region, and (iii) intraoral vibration. This study focused on the physical mechanism of mucus separation in the laryngeal region. A numerical

analysis was performed, coupling the Eulerian wall film model and Lagrangian discrete phase model to a numerical airway model that accurately reproduces the dentition in the oral cavity based on the computed tomography data of an adult male volunteer. Particularly, we reported on the comparison of prediction results using numerical airway models with different oral cavity shapes—that is, oral cavity opening area and its volume—that consider individual differences, as well as changes in the amount and location of droplets/droplet nuclei generation during continuous coughing. When the shape of the oral cavity was changed, the total amount of droplets/droplet nuclei generated via cough event also changed according to the change in exhalation jet profiles. Under the condition of coughing twice in a row, the total amount of droplets/droplet nuclei generated by the second cough was significantly reduced.

How common environmental sensors influence occupants' perception and interaction with the built environment: an in-situ experiment in a university in China

Jia Du, Hao Yang, Guoyu Zhang, Bin Chen, Jie Deng
Dalian University of Technology, China, People's Republic of

Energy conservation in buildings plays a crucial role for achieving the global target of Net Zero Emissions. Low energy use in buildings relies on not only energy-efficient technologies but also the green transition of consumers' behaviors. Feedback is one of the most effective behavioral interventions in residential buildings. However, existing feedbacks mostly centered around energy use records and overlooked comfort needs of occupants, whose adaptive behaviors in the built environment result in energy use. Previous studies suggested that people would like to know about indoor environment quality (IEQ) in addition to energy use information.
This study aims to explore how real-time IEQ display with common environmental sensors, as a straightforward and economical feedback strategy, influences occupants' perception and interaction with the built environment. Particularly, this study looked into the operation of windows and air conditioners in summer. An in-situ experiment was conducted in a university student residence in northern China. Non-intrusive sensors were used to collect environmental and behavioral data during the experiment, e.g., indoor and outdoor air temperature, relative humidity, concentration of carbon dioxide, open/closed state of windows and on/off state of air conditioners. Twenty-four male undergraduate students participated in this two-stage experiment and were divided into three groups. In the first stage, all groups were monitored without IEQ display. In the second stage, one group kept the same and the other two were provided with two kinds of IEQ displays and related knowledge cards. Meanwhile, physical environment measurements and subjective questionnaire surveys were carried out before, between, and after the two-stage experiment, investigating participants' indoor environment sensation and acceptance. Results showed that IEQ display could support a better perception of indoor thermal environment, and help avoid excessive space cooling and encourage proper natural ventilation. The findings are to inform occupant-centric feedback and control strategies.

【HUMAN 05: Thermal Comfort】

10th December, 10:45am ~ 12:00pm

Session Chair: Keiichiro Taniguchi, The University of Tokyo

Session Chair: Mingyang Qian, Tsinghua University

Study on thermal environment planning to social implementation of heat control technology in outdoor space

Sae Kyogoku[1,2], Hideki Takebayashi[1]
[1]Graduate School of Engineering, Kobe University, Hyogo, Japan.; [2]Acorn Corporation Inc.

Various heat island countermeasures have been proposed, implemented and their effectiveness verified. This study focused on the implementation of two heat countermeasure technologies: air cooling with mist and retroreflective materials (upward reflective materials). The effect of mist air cooling is related to human perception of temperature and humidity. It is also characterized by the fact that changes in the distribution of temperature and humidity occur up to a distance from the spraying location. For social implementation, it is necessary to evaluate the effect based on these characteristics in the same framework as solar shading and covering improvement. The purpose of this study was to organize the relationship between temperature and humidity distribution and SET*, and the effect of mist was evaluated based on the measurement results. Under ideal conditions, where all water droplets of mist evaporate, SET* is reduced and heat is mitigated. When mist was sprayed on hot air, the amount of temperature and humidity change was found to increase. Under conditions with high wind velocity, the mist was found to be diffused and less effective. Temperature reduction was observed in the range of approximately 2.0 m from the spraying position. Previous studies of retroreflective materials have reported their effectiveness by targeting the southern surface. In mid-latitude cities such as Japan, heat protection on vertical surfaces is prioritized for introduction on the east and west surfaces, where direct solar radiation is greater. The indoor and outdoor radiation environment on the east and west faces of an actual building was evaluated by measurement and calculation, comparing three types of film: upward reflecting film, general thermal barrier film and no film. The introduction of Upward reflective film on the east and west surfaces was found to improve the indoor thermal environment without worsening the outdoor thermal environment.

Proposal to improve thermal comfort models for better evaluation of mist evaporation cooling for people wearing protective clothing

Craig Edward Farnham, Jihui Yuan, Kazuo Emura
Osaka Metropolitan University, Japan

A model in needed to better evaluate the use of PPE (personal protective equipment) in hot environments where low-cost heat stress countermeasures such as mist fan cooling can be deployed. The 2-node models used in international standards of thermal comfort (ASHRAE 55) and worker safety in hot environments (ISO7933) do not account for wetness of the outer clothing layer. Several simple adjustments to lines in the ASHRAE 55 algorithm code were made to see if they could accurately match experimental measurements of mist fan cooling effect on a thermal mannequin wearing work clothes and PPE in hot outdoor summer conditions. It was found that the modified model somewhat matches experiment cases with bare skin and work clothes, but not the PPE cases. A more fundamental adjustment of the model is needed to handle multiple clothing layers with unique temperature,

water vapor and wetness values for each, similar to a multi-layer wall heat and mass transfer calculation. Uncertainties in air temperature in mist and wetness fractions of the clothing are further challenges.

Local Heating Operation Strategy by Considering Personal Heart Rate Variability During Sleeping and non-sleeping Period

Ji-Won Bae, Jong-Eun Lee, Jae-Han Lim
Department of Architectural & Urban Systems Engineering, Ewha Womans University, Republic of Korea

The standards for zero-energy buildings in South Korea have improved thermal insulation and airtightness in apartments, reducing daytime heating needs but increasing the necessity of maintaining good sleep health with nighttime heating operation. Although smart boilers and control systems show potential, current thermostats do not address the physiological needs of individual occupants. Research on heating control technologies that consider occupants' physiological characteristics is essential for energy savings and comfortable thermal environments in smart buildings. This study aims to develop a local heating operation strategy for individual occupants to achieve comfortable sleeping conditions by analyzing their heart rate characteristics using wearable sensors. To this end, experiments were conducted in April with five female participants in their twenties, using non-sleep and sleep conditions in a laboratory chamber at Ewha Womans University. And a sleep stage classification algorithm was developed, and the analysis between individual local heating device setpoints and sleep quality revealed various patterns among subjects, attributed to individual differences such as BMI, sleep habits, and thermal preferences. Additionally, the correlation between sleep quality and HRV variables was analyzed, confirming that variables like Mean RR, SDNN, Mean HR, and RMSSD showed high reliability. The study concludes that integrating heart rate characteristics into heating control strategies can significantly enhance energy efficiency and thermal comfort in smart buildings. Future research should explore long-term impacts and additional methods to further improve energy efficiency and occupant comfort.

Comfortable urban development based on human flow analysis - A pilot study in Toyohashi city –

Takashi Ito, Yasuhiro Shimazaki, Masaki Tajima
Toyohashi University of Technology, Japan

Toyohashi City experiences hotter weather during summer and the city government aims to improve the quality of life for urban stayers in downtown area especially around the main station, as a “Walkable City.” Mobile observations were made at 16 points in urban areas, stationary observations were made in a suburban area, and the human thermal load was evaluated for the human thermal environment. The relationship between human thermal load and outdoor urban morphologies was investigated by measuring the sky view factor and ground surface reflectance. The human flow was also measured to create an active space in front of the station. It was found that there was a relationship between human thermal load and human flow, and that human flow tended to be higher in areas with a good human thermal environment. Therefore, because it is necessary to take measures to reduce the human thermal load, we would like to revitalize the area around Toyohashi Station by utilizing effective measures from detailed urban simulations

Age Effects of Heat Acclimatization for Prevention of Heat Stroke by Bathing

Aya Yokoe[1], Toshiki Watanabe[2], Motoi Yamaha[1], Yuhi Baba[1]
[1]Chubu University, Japan; [2]Sinryo Corporation

This study investigates the efficacy of heat acclimatization via exercise and bathing as a preventative measure against heat stroke, focusing on the variances between elderly and younger adults.
The participant group comprised 20 individuals: 10 young men, 5 elderly men, and 5 elderly women. The young men were further categorized based on their bathing routines: daily bathing in a bathtub versus daily showering. These subjects participated in laboratory experiments conducted in May and June (before midsummer), July (during midsummer), and September (after midsummer). The experimental protocol involved a 20-min rest in a room simulating an indoor environment, followed by 10 min of exercise on a bicycle ergometer in a room mimicking on outdoor setting. Post- exercise, subjects returned to the indoor room for a 40-min recovery period. Measurements included sweat rate, skin temperature, deep body temperature, blood flow, and thermal sensation, assessed through a questionnaire.
Results indicated that both elderly and young adults maintained lower deep body temperature before midsummer compared to after, with significant period-based variations ($p = .000257$ for young adults; $p=.00710$ for elderly). Among young adults, those with bathtub bathing habits exhibited temperature differences before and after midsummer, whereas those who showered showed negligible period-based differences.
Regarding thermal sensation, young adults exhibited no significant temperature difference between the two periods, whereas elderly subjects showed a marked difference from pre-midsummer to midsummer ($p = .0032$).
These findings suggest that while bathing can promote heat acclimatization, its efficacy may be limited in elderly individuals.

【SYSTEM 07: HVAC System】

10th December, 10:45am ~ 12:00pm

Session Chair: Makiko Ukai, Nagoya University

Session Chair: Gerui Sui, Southeast University

Cooperative Control of Multiple Air-Conditioning Systems in a Zone: A Case Study of Variable Refrigerant Flow Systems

Taizo Shimo[1], Fuyumi Iijima[1], Eikichi Ono[1], Kuniaki Mihara[2]
[1]Kajima Technical Research Institute, Japan; [2]Kajima Technical Research Institute Singapore, Singapore

It is common for a single zone to have two air-conditioning systems: one for conditioning outdoor air for ventilation (outdoor air AC) and the other for maintaining room temperature (circulation air AC). However, their controls are independent, which can lead to energy waste. To address this, this study aims to quantify the energy-saving potential of a cooperative control that optimally allocates the cooling/heating load of the zone to each air-conditioning system. The study used an office space with two variable refrigerant flow (VRF) systems for simulation and experimentation. The process involved evaluating the energy-saving potential through virtual experiments using a calibrated simulation model to explore optimal load allocation at hourly intervals, and then applying the simulation-based optimization to the actual systems. Results showed that the cooperative control reduced total energy consumption by 9% compared to independent control. This was achieved by shifting the load from the outdoor air AC to the circulation air AC while maintaining indoor comfort. Additionally, experimental results demonstrated a 21% decrease in energy consumption by manipulating the supply air temperature setpoint of the outdoor air AC for optimal load allocation. These findings highlight the wide applicability of cooperative control in both new and existing buildings, thanks to its energy-saving potential and ease of implementation.

Verification of the effect of a desiccant device utilizing air conveyed by a ducted central air-conditioning system

Daisuke Umemoto[1], Koji Fujita[2], Keizo Yokoyama[3], Takashi Akimoto[3]
[1]Panasonic Homes Co.,Ltd, Japan; [2]Kindai University; [3]Shibaura Institute of Technology

In recent years, homes in Japan have become more highly insulated, and the adoption of ducted central air conditioning systems that heat and cool the entire home is on the rise. These systems are expected to improve indoor comfort, but when the indoor temperature is increased during winter, the indoor relative humidity decreases. Home humidifiers that require a water supply are used to counteract dryness, but there is a risk of microbial growth if they are not properly cleaned.
The purpose of this research was to realize a humidification method that suppresses the risk of bacterial growth. We investigated the possibility of using a desiccant device to absorb and release moisture using the heat conveyed by a ducted air conditioning system. In this study, we first measured the humidification effect in a house equipped with the system. Next, a computational model was constructed to quantitatively verify the humidification effect under standard weather conditions. By operating this device, the effect of increasing indoor relative humidity by 7% to 11% was measured. In addition, the calculated value of the daily cumulative humidification amount using the constructed calculation model was 7.0 L/day, which was roughly in agreement with the measured value of 7.3

L/day. In addition, the calculations were confirmed to reproduce the tendency for a large amount of humidification to be secured when the heating load is high, similar to the actual measurement results.

Development of a simulation tool integrating the heat source system including the ground source heat pump, the air-conditioning system, and the building thermal environment

Takao Katsura[1], Eisuke Togashi[2], Yuki Nabeshima[3], Katsunori Nagano[1]
[1]Hokkaido University, Japan; [2]Kogakuin University, Japan; [3]Shizuoka Institute of Science and Technology, Japan

Ground Source Heat Pump (GSHP) systems are gradually being introduced in Japan because they were defined as a renewable energy source in 2009 and have high potential for introduction as a renewable energy heat utilization technology. On the other hand, in order to accurately simulate GSHP systems, it is required to accurately simulate buildings and air-conditioning systems and to combine them as an ideal method.
In order to combine the calculations of building thermal load and HVAC equipment with the GSHP system and other heat source equipment, a methodology using standard input/output was applied to link subprograms in different program languages. The building thermal load calculation was developed in C#, the HVAC calculation was developed in Python, and the GSHP system calculation was developed in Basic language. Furthermore, the authors developed a methodology to give input sheets of WEBPRO's standard input method as thermal load and air conditioning conditions, and a methodology to select the GSHP system according to the type of air conditioning.
The main program and subprograms (heat source system (GSHP system) plug-in, air conditioning system plug-in, and heat load plug-in) that serve as the calculation engine of the integrated design tool were built on the cloud. Furthermore, a user interface for setting analysis conditions and a graphical display of the results are provided on the web so that users can freely set analysis conditions, perform analysis, and check the results.

Influence of housing performance and lifestyle on occupants' health and environmental load: A case study on thermal insulation, air-conditioning schedule, and windows direction

Mao Serikawa[1], Wataru Umishio[2], Junta Nakano[3], Takashi Akimoto[4], Toshiharu Ikaga[5], Shuzo Murakami[6]
[1]Kanagawa University; [2]Tokyo Institute of Technology; [3]Hosei University; [4]Shibaura Institute of Technology; [5]Keio University; [6]Institute for Built Environment and Carbon Neutral for SDGs

The evaluation framework for thermal insulation performance in Japan was revised in 2022 to realize carbon neutrality. Grades 5–7 were stipulated to evaluate houses with performances exceeding the current Grade 4 standard. High-performance houses can potentially reduce health problems caused by cold temperatures; however, such houses may experience overheating even during autumn and winter. We evaluated the energy performance and thermal environment of a detached house in Kagoshima, Japan, through a simulation. The indoor temperature, cooling and heating loads, and energy consumption were calculated using the Building Energy Simulation Tool Program for Housing Calculation. The considered parameters included thermal performance, air-conditioning schedule, and primary orientation of the windows in the house. Using the calculated indoor temperature, we evaluated occupant health and the number of days with overheating. The CO_2 emissions corresponding to the energy consumption of the house were also calculated. The study shows that higher thermal insulation reduces CO_2 emissions and protects occupant health from cold indoor environments. In intermittent air-conditioning operation, the heating and cooling loads processed by the air conditioners,

energy consumption, and CO2 emissions for grade 7 were lower than those of grade 4 by 7.4 GJ/y, 7.1 GJ/y, and 0.3 t-CO2/y, respectively. Furthermore, indoor environment and energy performance improved as the thermal performance increased. In the continuous air-conditioning operation cases, energy consumption decreased significantly with increasing thermal performance. The orientation of the windows did not significantly affect the evaluation results for cold winter environments. However, it affected the number of days that experienced overheating. Although the energy consumption was similar for houses with western and eastern windows, the number of days with overheating for the case of western windows was higher than that for eastern windows. The study concluded that houses with high thermal insulation and appropriate solar radiation control should be promoted.

Whole-Building HVAC Fault Detection and Diagnosis with the 4S3F Method: Towards Integrating Systems and Occupant Feedback

Martin Mosteiro-Romero, Ziao Wang, Chujie Lu, Laure Itard
Department of Architectural Engineering and Technology, TU Delft, Netherlands

Automated fault detection and diagnostics (FDD) can support building energy performance and predictive maintenance by leveraging the vast amounts of data generated by modern building management systems. Diagnostic Bayesian Networks (DBN) offer a particularly promising approach due to their robustness, flexibility and scalability. However, FDD applications in whole building systems are rare, as they require the integration of different building subsystems, with their own potential faults and symptoms, which increases complexity and makes the resulting DBNs system-specific. In order to overcome these limitations, the 4S3F (four symptoms and three faults) method offers a simplified, adaptable framework for FDD implementation across building systems.
In this paper, we implement the 4S3F methodology to a whole-building HVAC system in a case study office building located in the Netherlands. Our methodology uses generic, aggregated representations of individual subsystems within the building, such that FDD methods for specific subcomponents can later be incorporated where available. We first define aggregated building system groups (boiler group, chiller group, hydronic groups, ventilation groups, and end user groups) and subsequently define generic faults that can be detected with the existing sensor infrastructure. This simplified system representation is then used to define a DBN to isolate the most probable system-level faults that lead to building-level symptoms. By focusing on the whole building system, this work aims to provide the groundwork to incorporate occupant feedback and behavior in FDD.

Tuesday, 10th December, 1:30 pm ~ 2:45pm

【DESIGN 09: CFD and Airflow】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Lup Wai Chew, National University of Singapore

Session Chair: Craig Edward Farnham, Osaka Metropolitan University

Development and Verification of a Floor Heating with Dynamic Insulation

Ryunosuke YONEKURA, Sihwan LEE
Nagoya University, Japan

In general floor heating systems (General Type), a portion of the supplied energy is used to raise the temperature of the insulation, leading to heat escaping from the underfloor, which necessitates countermeasures. This study proposes a floor heating system with dynamic insulation (DI Type) to assess its effectiveness in saving energy. The energy-saving potential of DI type system was investigated by comparing it to a conventional floor heating system. Both experimental model measurements and computational fluid dynamics (CFD) analysis were employed to evaluate heat loss from the underfloor surfaces. Reduced-scale models demonstrated that DI Type significantly reduced heat loss from the underfloor surface, achieving reductions of nearly 100% compared to General Type. Full-scale CFD analysis also confirmed the energy-saving benefits, although with a reduction of approximately 40%. These results indicate that DI Type effectively minimizes heat loss by utilizing porous material to control airflow and reduce heat transmission. Despite minor discrepancies due to turbulent airflow, the overall accuracy of the experimental measurements and CFD analysis was validated. Therefore, the proposed floor heating system with dynamic insulation is shown to be an effective energy-saving solution, highlighting its potential for practical application in residential buildings.

Effect of Different Colors and Installation Methods of Roller Blind on Room Temperature Distribution

Dmitri Kai Zhun Kua[1], Kozo Takase[2], Masayuki Mae[3], Naoko Kishimoto[4], Rong Rong Lei[5], Hiroshi Satake[5], Ryota Satake[5]
[1]Graduate School of Science and Technology, Tokyo University of Science, Japan; [2]Tokyo University of Science, Japan; [3]The University of Tokyo, Japan; [4]YKK AP Inc.; [5]Graduate School of Engineering, The University of Tokyo, Japan

To improve indoor thermal environment and energy efficiency, it is crucial to enhance the thermal insulation, shading performance, and daylighting of fenestrations. Solar gain, or direct gain, is one of the commonly used methods for reducing heating load in winter by utilizing natural sunlight. However, conventional direct gain often led to overheating and privacy issues, making window attachments inevitable, furthermore essential for maintaining optimal indoor conditions. Recent research by JI (2023) demonstrates that integrating roller blind with Phase Change Material (PCM) on the ceiling effectively reduces heating loads and improves indoor thermal environment.
In this study, the authors aimed to evaluate the impact of different roller blind colors and installation methods on indoor thermal environment. Computational Fluid Dynamics (CFD) simulation was used to model and verify the accuracy of reproducing the indoor thermal environment with roller blind,

using actual measured data collected in a full-scale experimental building.
This study compared different roller blind colors and installation methods, including front-mounted, curtain rail-mounted, ceiling-mounted, and ceiling-mounted with a panel on the indoor thermal environment under the same climatic conditions. The results indicate that, from the perspective of thermal environment and solar heat gain in winter, roller blind with high solar reflectance is effective for east-facing openings, and roller blind with high solar absorption is effective for south-facing openings. In addition, the front-mounted installation proved to be the most effective in winter compared to the other installation methods. Thus, it offers a promising solution for mitigating overheating and improving the indoor thermal environment.

Effects of Nozzle Radius on Induction Ratio of Active Chilled Beams

Kairui Zheng, Chandra Sekhar, Lup Wai Chew
National University of Singapore, Singapore

The global increase in building energy consumption necessitates the development of energy-efficient technologies to mitigate environmental impacts. Active Chilled Beam (ACB) systems are known for their lower energy consumption compared to traditional HVAC systems. In an ACB, the supply air jets induce the indoor air which passes through cooling coils and returns to the indoors with the supply air. The ratio of induced air to the supply air is called the entrainment ratio or induction ratio (IR). IR typically ranges between 2 and 6. A higher IR means more induced airflow under the same supply air flow rate. Therefore, understanding how ACB design affects IR is important to achieve high efficiency. This paper examines the impact of ACB nozzle radius on IR. Using computational fluid dynamics (CFD) simulations, a set of parametric study is conducted by varying the inlet velocity and nozzle radius. The CFD results reveal that IR remains around 4.2 when the supply air velocity is increased gradually from 0.75 m/s and 5.33 m/s, confirming that IR is independent of the supply air velocity. Decreasing the nozzle radius significantly increases the IR, where an IR of up to 9.0 can be achieved with a small nozzle radius of 2 mm. Guided by the findings that nozzle radius can significantly affect IR, Future work can focus on other geometrical parameters of the nozzle, such as nozzle length, nozzle angle, and the spacing between nozzles, to increase the efficiency of ACB systems.

Investigation of reattachment length of recirculation flow around a wall-mounted square cylinder in RANS

Zitao Jiang[1], Yuanyuan Lin[2], Mats Sandberg[2], Tomohiro Kobayashi[1]
[1]Osaka University; [2]University of Gävle

The flow around the bluff influences urban ventilation, pedestrian wind comfort, and urban microclimate. The geometry of the bluff body largely influences the flow regime and consequently has an impact on the urban climate. Current work investigates the effect of the dimensions of a wall-mounted square cylinder on separating and reattaching flow length on the front floor (X_F), roof (X_R), side walls (X_S) and leeward floor (X_L) of an isolated building. The RNG k-ε model could reproduce the reverse flow above the roof, thus it was used for the present study. As a result The building streamwise length does not influence the reattachment length at the roof level. Still, it affects the reattachment length at leeward and side walls, and there is a threshold over which the reattachment length at leeward becomes a nearly constant value. The building width has the largest effect on X_L and X_R among the three dimensions. The prediction model for reattachment length X_R is proposed and discussed.

【DIGITAL 05: Advanced Techniques】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Adrian Chong, National University of Singapore

Session Chair: Yusuke Arima, Kyushu University

A.I. Real-time Lift Door Inspection System

Jimmy K.K. Chan[1], Jason J.S. Au[1], Scotty C.H. Kwok[2]
[1]Electrical and Mechanical Services Department, HKSAR CHINA; [2]Sebit Company Limited

This paper presents a proof-of-concept of the use of A.I. Real-time Lift Door Inspection System which can revolutionize lift maintenance. Lift service interruptions caused by malfunctioning lift doors are unavoidable. Unlike traditional inspection, the fully automated system will greatly reduce the need for lift technicians to conduct inspections inside the lift shaft. The system consists of a versatile stand-alone installation suitable for all types of lifts. The installation involves electronic sensors, cameras, microphones, an edge computer, and a 5G router. As the lift car moves along the shaft, a camera captures the landing doors' images to assess their integrity and alignment. At the stop of each designated floor, another camera monitors the movement of both the car doors and landing doors, while a microphone monitors any abnormal screeching sounds when the doors are in motion. A set of ultrasonic sensors also detects angular misalignments by measuring the distance between the car doors and landing doors. Collected data are then processed by an edge computer and wirelessly transmitted through 5G to a cloud computing platform. Smart analytics on video and audio data are performed to analyze the health of lift doors for predictive maintenance. Alerts are also generated to prompt technicians to take necessary actions. The system offers automated and 24/7 continuous monitoring, enhanced safety for lift technicians and passengers, data-driven predictive maintenance, and improved maintenance quality. This paper will share the experience, effectiveness, and challenges of developing a new concept of system for inspection and predictive maintenance strategy for lift installations.

Development of Environmental Soft Sensors Using cDCGAN to Estimate the Indoor Thermal Environments Distribution

Haichen Xu, Keiichiro Taniguchi, Yasunori Akashi
The University of Tokyo, JAPAN

Computational Fluid Dynamics (CFD) analysis is commonly used to obtain the distribution of indoor physical environments but is time-consuming and unsuitable for real-time temperature distribution generation. High-density sensing can provide insights into environmental distribution, but there are physical constraints on sensor placement. This study aims to develop a machine learning-based approach using conditional Deep Convolutional Generative Adversarial Network (cDCGAN) for real-time generation of indoor temperature distribution maps aligned with individual thermal comfort preferences. Sensor data from the University of Tokyo's Mejirodai dormitory are used as condition vectors to train the model. Conditional vectors significantly improve the accuracy of generated images, allowing precise control of temperature distributions. Wind speed distribution, challenging to predict due to sensor limitations, is addressed using CFD data for training. This approach enhances the understanding of indoor environments, providing more comfortable and energy-efficient conditions for occupants by generating real-time, high-precision distributions of temperature and wind speed.

Study on Interpretability of Energy Optimization Control using XAI

Koki Miyano[1], Ken Takahashi[1], Shintaro Ikeda[2,3], Ryozo Ooka[3]
[1]The University of Tokyo, Japan; [2]Mikoto Strategy Corporation, Japan; [3]The University of Tokyo, Institute of Industrial Science, Japan

As a complex deployment of solar power systems and energy storage systems at both supply and demand ends increase, integration of Artificial Intelligence (AI) into building control systems has become a growing trend in recent years. Although the implementation of AI is expected to give benefits on many areas, the lack of transparency in AI algorithms has hindered trust and application in real-world situations. On the other hand, eXplainable AI (XAI) has come under the spotlight as they can interpret complex AI models. However, the dependence on a single XAI method may cause biased interpretations, which can lead to poor comprehension of AI control mechanisms.
This study aims to interpret decision-making process by applying XAI to the results of energy optimization control using Reinforcement Learning (RL). Soft Actor-Critics (SAC) algorithm is implemented to battery storage control for reducing carbon emissions and electricity costs. Based on the results, five different XAI methods, which are SHapley Addictive exPlanations (SHAP), Permutation Importance (PI), Partial Dependence Plot & Individual Conditional Expectation (PDP&ICE), Local Interpretable Model-agnostic Explanations (LIME), and Deep Learning Important FeaTures (DeepLIFT) are utilized to evaluate and compare the influence of each observation on the agent's decision-making process.
The results indicate that hour and solar generation are the two dominant observations in the SAC and also, it suggested the possibility of the difference of control in global trends and local trends. The application of different XAI methods provides multiple perspectives on the importance of each feature in energy optimization control, which leads to a better understanding of the internal structure of AI models, contributing to facilitate the formulation of enhancement strategies that are comprehensible to humans.

Evaluation of building and system energy consumption using baseline analysis method with Random Forest

Yudai Ishiguro[1], Naoki Takahashi[2], Kazusa Koike[3], Hideharu Niwa[4], Hideki Tanaka[5]
[1]NAGOYA UNIVERSITY, Japan; [2]Nikkei Sekkei, Ltd; [3]NIKKEN SEKKEI RESEARCH INSTITUTE; [4]NIKKEN SEKKEI RESEARCH INSTITUTE, Dr. Eng.; [5]Prof, Campus Planning & Environment Management Office, Nagoya Univ. Dr. Eng.

The introduction of the Building & Energy Management System (BEMS) is being promoted; therefore, large amounts of energy-related data are available. However, many BEMS datasets have not been fully utilized in Japan. In this study, to use such data, a baseline energy consumption estimation model (BL-Model) with machine learning was applied to evaluate building energy consumption. Specifically, we use variable energy-related data measured by BEMS in a hospital for three years (from 2017.4 to 2020.3), with the base year for the evaluation being 2017. In this method, a machine learning model using Random Fost was built based on actual data from FY 2017 to create an estimated energy consumption model for the entire building, multiple departments, and each heat-source equipment. The primary variable data of temperature, humidity, year, month, and time were used to construct the estimation model, the number of patients, and the amount of heat, depending on the purpose. The BL model was used with FY 2017 as the base year to estimate energy consumption at each time point, and then the estimated and actual values were compared. As a result, building energy consumption increased compared to the estimated values, confirming that heat source equipment is the main factor that increases building energy consumption. Furthermore, owing to the change in the

operation method of the heat source equipment, each coefficient of performance (COP) was lower than the estimated values and lower than the FY 2017 base.

Stochastic and interpretable prediction of industrial electricity consumption using Temporal Fusion Transformer

Hansol Shin, Wun-Cheol Jeong, Chungho Lee, Tae-Wook Heo
Electronics and Telecommunications Research Institute, Korea, Republic of (South Korea)

This study presents a novel approach to stochastic and interpretable prediction of electricity consumption in industrial facilities using the Temporal Fusion Transformer (TFT) model. Leveraging weather observation and short-term forecast data from the Korea Meteorological Administration (KMA), the TFT is applied to predict power usage in four energy-intensive industry facilities. The TFT's ability to manage uncertainties through multi-horizon forecasting is combined with interpretable insights into the importance of features such as temperature, humidity, precipitation, and wind speed. In this study, the observed weather data improves prediction accuracy across most facilities. On the other hand, the forecasted weather data increases prediction uncertainty in some facilities. The proposed approach aims to enhance the stability of regional power grids by using short-term forecasts to predict local electricity demand accurately. Also, by evaluating the time-series variable importance related to weather observations and forecasts, it is possible to assess whether a factory energy use relies on weather-dependent factors, such as cooling, heating, or lighting energy consumption.

【DIGITAL 06: Prediction】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Yutaka Shoji, Kajima Technical Research Institute

Session Chair: DeukWoo Kim, Korea Institute of Civil engineering and building Technology

Chance-constraint MPC approach to optimize building energy system operation considering prediction uncertainties

Parastoo Mohebi[1,2], Zhe Wang[1,2]
[1]Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China; [2]HKUST Shenzhen-Hong Kong Collaborative Innovation Research Institute, Futian, Shenzhen, China

Buildings significantly influence global energy consumption and greenhouse gas emissions. Achieving carbon neutrality necessitates optimizing building energy systems during operation. This study presents a novel framework that quantifies prediction uncertainties by utilizing system parameter distributions of a grey-box Resistor-Capacitor (RC) model obtained via parameter identification method. An optimization model with chance constraints is developed to manage uncertainties and assess their impact on Model Predictive Control (MPC) performance in terms of energy cost and thermal comfort. Findings demonstrate that increasing the confidence level tightens comfort boundaries, resulting in reduced thermal discomfort alongside higher energy costs. Additionally, accounting for uncertainties ensures that MPC outperforms the baseline Rule-Based Control (RBC).

Study on the Prediction of CO2 Emission Reduction Effects for the Formulation of CO2 Emission Reduction Strategies in University Buildings

Naoto Yoshida[1,2], Hideki Takebayashi[1]
[1]Graduate School of Engineering, Kobe University, Hyogo, Japan; [2]Acorn Corporation Inc.

The measurement conditions of electricity consumption in 94 buildings on the Kobe University campus, excluding the hospital and the Faculty of Medicine, are insufficient for the comprehensive study of energy conservation plans. This is because only 11 buildings have separate measurements for single-phase and three-phase electricity. With the aim of extracting effective information for studying energy conservation plans from the current measurement data, the time variation characteristics of electricity consumption were analyzed at 38 locations. Through cluster analysis, the clusters at many measurement locations were classified into three categories: weekday clusters (including many weekdays), holiday clusters (including many weekends and holidays), and clusters characterized by high air conditioning loads, such as days with daily average temperatures above 27 °C or below 10 °C. In the humanities buildings, there are several buildings in which days with time change characteristics corresponding to holidays account for more than 50 % of the year, resulting in a low priority for energy conservation measures. The number of days corresponding to the heating and cooling season cluster was small, and the distinction between weekday- corresponding and heating and cooling season clusters was not clear in some buildings. In many buildings, it was considered possible to classify the holiday- corresponding cluster as base electricity consumption, the difference between the weekday-corresponding and holiday-corresponding clusters as electric lighting and outlets electricity consumption, and the difference between the heating and cooling season-corresponding and weekday-corresponding clusters as heating and cooling electricity consumption. This study used only time-

specific electricity consumption data for statistical classification. Consequently, electricity consumption by facility use was obtained more simply.

Fundamental Study on Developing Prediction Model for Operation Performance of Heat pump system Coupling with Rainwater tank

Hamin Eu[1], Gyuyong Kim[1], Gyuyoung Yoon[2], Mariko Matsubara[2], Yaechan Lee[1], Seunghyeon Han[1], Junyoung Park[1], Younsung Choi[1]
[1]Chungnam National University, Korea, Republic of (South Korea); [2]Nagoya City University, Nagoya, Japan

Recently, flood damage caused by abnormal climate conditions has increased in Korea. To prevent this, the construction of underground rainwater tanks (RW tank) in cities is increasing. These RW tank are also expected to be used as a heat source and heat sink for heat pumps because they store a large amount of rainwater. Therefore, in this study, a Rainwater Tank Heat Pump system (RWHP) was developed using an underground RW tank as a heat source. The RWHP test bed was installed in Republic of Korea, and data was collected over a two-year period. Through field data analysis, the effect of precipitation and water level on the temperature of the RW tank was analyzed. In addition, the factors affecting the temperature of the RW tank were identified. As a result, it has been confirmed that the temperature behavior of the RW tank depends on the precipitation and water level. These precipitation and water levels affect how much the RW tank can accommodate thermal energy from the heat pump. Also, the temperature of the RW tank is affected by various variables such as cooling load, heating load, and operation mode. Meanwhile, the cooling COP of the RWHP ranged between 4.5 and 2.5. The heating COP ranged between 3.5 and 2.5. The RWHP's COP was affected by the changing of temperature of RW tank. It is important to predict the temperature of the RW tank to ensure optimal operation and performance of the RWHP. Therefore, various machine learning techniques were used to develop a model for predicting the temperature of the RW tank. A total of three models were reviewed with random forest bagging, gradient boosting, and Long Short-Term Memories (LSTM) to determine a machine learning model with high accuracy.

A method for predicting unmeasured disturbances in model predictive control of Thermally Activated Building Systems(TABS) using grey box-NN Models

Xiaochen Yang, Dingzhou Liu, Ruizhi Wang, Yixuan Jiang
Tianjin University, China, People's Republic of

TABS embeds the hydronic pipes inside the building envelope for heating or cooling purpose. The special layout enables TABS to provide high level of thermal comfort, and also the energy flexibility for the effective demand side response. However, the large thermal inertia of TABS results in ambiguous correlation between the input variables and the system dynamics. Moreover, the limitation of measuring the stochastic heat disturbances in practice also increases the difficulty of establishing the TABS models with high accuracy. As a result, the performance of the coupled optimal control strategy can be jeopardized, and the maximized utilization of the provided flexible energy cannot be achieved. To address the above mentioned issues, we propose an innovative model framework, which couples the grey-box model of the TABS with a prediction module for the unmeasured disturbances. First, the grey-box model of the reference TABS system is developed and identified with the measured parameters, and the unmeasured disturbances are implicitly considered. A neural network(NN) model is then applied to predict the disturbances. The NN module is embedded in the grey-box model framework, and was trained using the historical measurements of the system operation data. Such

framework can ensure the physical rationality of the predicted thermal disturbances values. The predicted disturbance is fed back to the grey-box model and improves the overall model precision. The model predictive control (MPC) strategy with the same objectives and constraints is developed and implemented in conventional system model, as well as the model with the NN disturbance predict module. The performances such as the energy costs and indoor thermal comfort of the two scenarios are compared. The stability and the efficiency of the adaptive framework are discussed.

Performance prediction of cooling tower based on physics-informed neural networks

Zehongyu Kang, Xin Zhou
School of Architecture, Southeast University, Nanjing, China

The energy consumption of air-conditioning systems accounts for a considerable part of the energy consumption of building operations, and the energy conservation and efficiency improvement of air-conditioning system operation control is of great significance. As an important radiating component in the air conditioning system, the cooling tower's outlet water temperature will directly affect the efficiency of the chiller. Accurately predicting the operating performance of cooling towers plays an important role in accurately implementing energy-saving control strategies for air conditioning systems. Among the existing models used to predict the performance of cooling towers, physical models have high prediction accuracy and strong interpretability, while data-driven model modeling is convenient and fast. Combining the advantages of the two types of models, this study attempts to establish a physics-informed neural networks (PINN) model for cooling tower performance prediction for the first time. In the experiment, it was determined that the optimal physical constraint proportion was 0.1, and the optimal number of training set samples was 20% relative to the test set. In case verification using this set of parameters trained models, the MRE of the PINN model was 1.61, which was 2.5 lower than the artificial neural networks (ANN) model, and the RMSE of the PINN model was 0.37℃, which was 0.71℃ lower than the ANN model. This study provides guidance and reference samples for predicting cooling tower performance when the training set is small.

【DIGITAL 07: Modelling and Application】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Da Yan, Tsinghua University

Session Chair: Miguel Martin Fehlmann, Delft University of Technology

Visualization and Impact Estimation of Multiple Faults in Chiller Plants Based on Automated Fault Detection and Diagnosis

Tatsuya Miyata, Shohei Miyata, Yasunori Akashi
The University of Tokyo, Japan

Research on fault diagnosis of HVAC systems has been a highly significant topic in reducing energy loss in buildings, and previous studies have proposed methods to diagnose single faults with high accuracy. However, the types of faults that can be diagnosed are often limited, and visualizing or interpreting their diagnostic results are not easy. Furthermore, it has also been pointed out that in real systems, multiple faults occur with various degrees of magnitude. The purpose of this study is to propose a new fault diagnosis method using a Variational Auto Encoder (VAE), enabling diagnosis of multiple faults. By learning the features of fault dataset, and mapping such data onto lower dimensional space, Fault-Map can be created, which allows the estimation of both the fault type and the fault impact. By applying this method to the system, single fault types could be diagnosed with an average accuracy of over 97%. Assuming the simultaneous occurrence of two types of faults, we conducted the diagnosis of multiple faults by mapping data into a higher-dimensional Fault-Map. As a result, at least one of the faults could be diagnosed with very high accuracy, exceeding 99%. The proportion of jointly diagnosed two faults was about 70%, which is not sufficiently high. By analyzing the behavior of points corresponding to multiple faults on the Fault-Map, the reason for the decrease in diagnostic accuracy was examined, and furthermore, by updating the operational data items used for training VAE, we tried to improve the diagnostic accuracy for combinations with low accuracy. In the future, reconsidering the method of creating fault data and devising maintenance plans can further improve the diagnostic performance.

Research on the development of a model for predicting building heat loads by using machine learning

Mariko Matsubara, Gyuyoung Yoon, Saya Yoshioka
Nagoya City University, Japan

This paper proposes a method for simplifying heat load input conditions that can be adopted during the schematic design stage, and to create a heat load prediction model. In addition, the heat load prediction model considers building properties and uses, and aims to reflect the latest conditions, such as thermal performance of building envelop and internal heat gain. First, the public buildings were designated as targets, and the input parameters for heat load calculation were simplified to reduce the number of man-hour worked. As a result, the number of input points was reduced by 71.4% compared without simplification, and the difference in the calculation results was within 3%. Also, to confirm the validity of the simplification method, a threshold value guaranteeing the validity for heat load calculation results was estimated, and solutions when the given condition exceeded the estimated threshold were discussed. Next, 510 cases were generated by using the simplified buildings, setting parameters for building attributes, thermal performance of building envelop, and internal

heat gain, and performing heat load calculations. Then, a heat load prediction model is created by Supervised Learning. For training machine learning, the output variables are set as the total building heat load and the internal sensible heat load on the typical floor. The input variables are 8 variables, including internal heat gain. Then, MATLAB2023a's regression learner was employed. Then, Heat load prediction models were obtained while the machine learning algorithms that showed the most fit were selected among the available algorithms. Finally, the accuracy of these heat load prediction models was verified to confirm that the heat load predictions were useful in practice. The results showed that the accuracy was within 5%, mainly for cooling load, which can be used for designing system capacity and benchmarking energy performance.

Long-term changes in time use and impacts on residential energy demand

Rumeng Yin, Yohei Yamaguchi, Andrew Marian Zajch, Hideaki Uchida, Yoshiyuki Shimoda
Osaka university, Japan

Occupants' activity patterns significantly impact energy demand in residential buildings, and these patterns are typically modeled using time use data. Though previous studies have identified long-term changes in activity patterns across different demographics, such changes have often been ignored in occupant behavior models. This study used Japanese time use survey data from 2001 to 2021 to analyze long term temporal changes in activity patterns. Using a hierarchical approach, we developed logistic regression model considering various demographic and household characteristics. Our findings reveal that total time spent on sleep, work and housework decreased across all demographic segments in 2021, indicating a significant shift in activity patterns. We observed a decrease in nighttime sleep probability and changes in housework and work time allocations. These results underscore the importance of incorporating long-term changes in occupant behavior models to enhance their accuracy and applicability. Future research can combine with machine learning methods and synthetic population to explore how shifts in activity patterns influence energy demand for urban scale regions.

Crowdsourced Campus Digital Twin for Building Performance Simulation Teaching and Research

Yu Qian Ang, Lester Ong, Jolyn Teo, Jielong Gan
National University of Singapore, Singapore

This paper highlights the potential of a novel crowdsourced campus digital twin platform in transforming building performance simulation (BPS) education and research. By providing a hands-on, interactive, and contextually relevant learning experience, the crowdsourced digital twin empowers students to develop critical skills in BPS while contributing to a growing repository of campus building models and simulation data. The platform serves as a centralized hub that hosts models (developed by students, for students) across various scales, from building level to urban scale. By incorporating campus building models with their respective building energy simulation templates, the digital twin enables students to engage with real-world scenarios and apply BPS in a meaningful context. Furthermore, the platform integrates simulation results for energy performance, daylight analysis, outdoor thermal comfort, and other relevant metrics, providing a live and interactive learning environment. Tutorials are also hosted on the platform to support students' learning journey. The platform and its content's crowdsourced nature allow it to grow across multiple student cohorts, with each group contributing to improving existing models or creating new ones.
The platform has been piloted with over 50 undergraduate students in a compulsory year-one course.

Teaching BPS to undergraduate students, particularly those with limited background knowledge, can be challenging. Balancing the learning curve, maintaining student engagement, and achieving learning outcomes requires careful consideration. Through developing and implementing the platform and its crowdsourced content, we have identified effective strategies to enhance student learning and engagement in BPS education.

Finally, the platform also serves as a valuable research repository, consolidating data across various scales and enabling the exploration of urban building performance phenomena. By leveraging the collective efforts of students and researchers, the digital twin platform fosters collaboration and knowledge sharing, leading to new insights and advancements in building performance simulation.

【HUMAN 06: Healthy Buildings】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Akihito Ozaki, Kyushu University

Session Chair: Weixin Qian, Harbin Institute of technology

Changes in Humidity Control Performance of Loess Brick Envelope with High Vapor Transmission Resistance Insulation and Improvement Measuresures

Huihua Liu, Haodong Nan, Haksung Lee
Chungbuk National University

Earth buildings have a long history of construction. Recently, as green building technologies gain prominence for conserving energy and reducing carbon emissions, earth, a natural material with inherent indoor environmental regulation capabilities, has regained attention as an eco-friendly option. However, to meet increasingly stringent energy-saving design standards, the installation of conventional insulation materials with high moisture permeability resistance in earthen walls, can diminish the envelope's ability to control indoor humidity while reducing heat loss. This study aims to analyze the impact of insulation on the humidity control capabilities of an envelope and indoor humidity in a house constructed with loess bricks to meet energy-saving design standards, and to propose improvement measures. A house with double-layered loess bricks and expanded polystyrene insulation was analyzed. Indoor temperature and humidity of the target house were measured during the summer, when both the temperature and humidity were high. Numerical modeling was conducted through detailed simulations of the experimental house. Using the constructed model, a parametric sensitivity analysis was performed to assess the effect of varying the materials of the interior and exterior loess bricks (such as concrete) and changing their thicknesses on the indoor humidity. No significant differences were observed in indoor humidity when the exterior wall material was replaced or when the thickness of the interior wall material was changed. However, when the loess material on the interior wall was replaced with concrete, the indoor relative humidity increased.

Hygrothermal Fluctuations in Concrete Spaces With Interior and Exterior Insulation by Glass

Haodong Nan, Huihua Liu, Haksung Lee
Chungbuk National University

This study analyzes the effects of the presence or absence and placement of glass windows on the indoor temperature and humidity environment under internal and external insulation conditions for concrete single-room buildings. Windows play an important role in a building's natural lighting, ventilation, and exterior design; however, they also have energy-efficiency vulnerabilities. Previous research has focused mainly on the issue of sensible heat, but this study emphasizes the importance of latent heat management related to indoor moisture. To this end, cases of no windows, windows only on the south wall, and windows on all four walls are simulated, compared, and analyzed. The simulation results show that indoor temperature and humidity fluctuations significantly differ depending on the arrangement of windows and the manner in which insulation settings, especially external insulation, are effective in increasing indoor temperature stability; however, as the window-to-wall ratio increases, so does the indoor absolute humidity, which may heighten the risk for moisture damage. Moreover, in the case of internal insulation, indoor humidity fluctuations increase because of low hygroscopic properties. This indicates that the hygroscopic property can be an important factor in

maintaining indoor environmental comfort and suggests that design methods such as windows and insulation have a significant impact on indoor moisture. This study seeks to explore an architectural design methodology that simultaneously considers energy efficiency and indoor comfort, while highlighting the importance of indoor humidity management.

Proposal of eco-friendly temporary housing to improve disaster response flexibility

Sungwoong Yang, Yujin Kang, Hyunseong Yuk, Sumin Kim
Yonsei University, Korea, Republic of (South Korea)

Natural disasters such as typhoons, earthquakes, floods, and infectious diseases, as well as man-made disasters such as war, create the need for temporary living spaces and facilities for isolation from specific situations. In response to this need, various types of temporary structures have been proposed. The definition of temporary buildings varies depending on the period of use and purpose, and the target of this study is temporary houses lasting from at least a few weeks to several months or more. Temporary buildings must be provided quickly through rapid supply, but energy consumption is not efficient, and a lot of waste is generated due to demolition after a disaster. This point is tied to the issue of sustainability in disaster response. Therefore, the temporary buildings provided need to be more energy efficient and environmentally friendly. Therefore, based on the high reserves of loess and its eco-friendly and energy-efficient characteristics, a temporary building that can be supplied quickly was proposed. Temporary structures are manufactured in a factory and procured to the site, and the walls are made of lightweight materials such as expanded vermiculite and perlite, making them highly lightweight and having excellent thermal conductivity. In addition, by adding composite materials with heat storage performance, thermal efficiency was improved, and energy reduction was attempted to maintain comfort. These buildings have been shown to be energy-saving in most climates in the Köppen climate, and because they are constructed with natural materials, their impact on the environment can be greatly reduced. It is believed that by using the temporary structures presented in this study, flexibility in disaster response can be secured and a sustainable society can be realized

A simulation of thermoelectric power generation system for lunar habitat

Seheon Kim[1], Hansol Lim[2], Sang-Hwan Park[1], Minseong Kim[1], Jae-Weon Jeong[1]
[1]Hanyang University, Korea, Republic of (South Korea); [2]Korean Institute of Civil Engineering and Building Technology, Republic of (South Korea)

Recently, there has been a significant increase in global demand for space missions and space research. One of the primary goals of these missions and research efforts is to develop and utilize rare lunar resources, necessitating the development of a manned lunar habitat. Despite development of the manned habitat is essential, the extreme temperature variations on the lunar surface, ranging from 90 K to 390 K, leaves significant challenges for constructing structures. However, these temperature fluctuations also can be an opportunity for the power-generating system with the thermoelectric generators (TEGs), which convert heat flux directly into electrical energy. Therefore, this paper aims to suggest and evaluate the suitability of a TEG-based power generation system for lunar habitation by simulating its performance under lunar environmental conditions. Concept of the thermoelectric power generation is introduced with the present findings, and detailed setup of the system and simulation process is presented as well. The result of the simulation is discussed with the influencing factors, pointing further research should be considered on the optimized design of the system. The findings of this study can contribute to foundational research for lunar manned missions, providing

insights into the development of sustainable power solutions and the broader implications for long-term lunar habitation and resource utilization.

Comprehensive hygrothermal evaluation of low-energy wooden apartments: focusing on the improvement thermal comfort

Yujin Kang, Ji Hun Park, Jihee Nam, Sumin Kim
Department of Architecture and Architectural Engineering, Yonsei University, Seoul 03722, Republic of Korea

The construction sector is increasingly focused on reducing greenhouse gas (GHG) emissions through innovative approaches to address global warming and climate change. The potential of cross-laminated timber (CLT), which stands out as a sustainable alternative to concrete and steel due to its superior insulation properties and carbon storage capabilities is a key area of interest. These attributes make CLT a valuable contributor to carbon emission reduction. Additionally, as a wood-based material, CLT not only enhances occupant well-being but also meets modern architectural and environmental standards. A through evaluation of wooden apartments incorporating CLT wall systems revealed a 9-10% decrease in GHG emissions compared to reinforced concrete (RC) structures under Korean climate conditions. Furthermore, the study highlighted effectiveness of CLT in maintaining a comfortable indoor environment by regulating temperature and humidity.

【SYSTEM 08: Building Energy Systems】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Daisuke Sumiyoshi, Kyushu University

Session Chair: Wei Wang, Southeast University

Assessing the effects of combined space cooling measures in reducing cooling demand and emissions in hot, humid Southeast Asian households

Mark Cel Estopare Gonzaga, Tomohiko Ihara
The University of Tokyo, Japan

Space cooling is increasingly becoming a major issue globally, more so for hot and humid climates such as Southeast Asia that traditionally relies on natural ventilation as well as cooled and/or open public spaces for thermal comfort. Access to space cooling studies currently focus on air conditioning penetration to determine cooling gaps, but for the region with low AC ownership, this does not represent actual cooling needs. In this study, building energy simulation is used to evaluate effective temperatures of a household in the Philippines, which are then used to assess thermal comfort based on ASHRAE adaptive comfort model and its SEA counterpart, using uncomfortable occupied hours (UOH) and degree-hours (UODH) as indices. Based on the results of the assessment, the bedrooms are considered thermally comfortable based on both models for all cases. The main zone shows uncomfortable temperatures from afternoon to evening, which can be reduced by window opening and use of AC, although further reduction of uncomfortable hours still needs to be studied. The two models show considerable differences especially in determining the extent of discomfort through UODH, indicating the need to develop models that better represent local conditions.

Evaluating a novel fan-powered variable air volume system installed in a large-sized office building

Fuyumi IIjima[1], Taizo Shimo[1], Naoki Onishi[2], Yukito Suzuki[2], Eikichi Ono[1]
[1]Kajima Technical Research Institute, Japan; [2]KAJIMA CORPORATION, Japan

Reducing air transportation energy in air-conditioning systems is vital for global carbon neutrality, especially in large-scale urban projects with district heating and cooling. Large-scale office buildings in Japan typically use variable air volume (VAV) systems, often resulting in energy inefficiency and poor indoor environments due to pressure loss from dampers and high minimum airflow rates (around 30%). To address these issues, a novel fan-powered VAV system was developed with three key strategies: (1) optimal static pressure distribution via fan-powered terminal units, (2) reduced minimum airflow rates for energy savings and better indoor control, and (3) coordinated terminal and air handling unit (AHU) controls for enhanced efficiency. Evaluation in a Yokohama office building showed improved dehumidification and acceptable indoor environments, achieving air transport factors (ATF) of 20–50 in summer and 10–20 in winter. A simulation indicated a 21% energy reduction from optimized pressure distribution and an additional 19% reduction by lowering airflow rates, showcasing the system's energy-saving potential.

Sensitivity of optimal control methods to load prediction accuracy: in the context of thermal load prediction-based control of thermal energy storage systems

Xiao Wang, Xuyuan Kang, Da Yan
Building Energy Research Center, School of Architecture, Tsinghua University, Beijing 100084, China

Accurate thermal load prediction is critical to control performance of thermal energy storage (TES) systems. However, thermal load prediction error inevitably happens. It is necessary to improve the optimal control methods by investigating their sensitivity to thermal load prediction accuracy. This study investigates 5 widely used optimal control methods under 10 different ice-based TES systems. Coefficient of variation (CV) of operation cost is used to evaluate the sensitivity. The results show that a reinforcement learning (RL)-based method is the least sensitive to cooling load prediction accuracy, with a CV of 0.396%. When cooling load prediction uncertainty is high, it is significant to select the RL-based method and focus on improving its performance. The understanding of the characteristics of optimal control methods facilitates the application of advanced control technologies for TES systems.

Simulation to evaluate the effect of waste heat recovery from underground parking spaces in residential buildings during winter

Yingdao NAN, Seheon Kim, Min-Geon Park, Suyeon Hong, Hye-Jin Cho, Beom-Jun Kim, Jae-Weon Jeong
Hanyang University, Korea, Republic of (South Korea)

Significant heat exists in the underground parking spaces due to the wasted heat from the automobiles, warming the space. This heat can be recovered to reduce-carbon emission. Therefore, this study aims for assessing the effect of recovering the heat in the underground parking space of residential building, especially during winter. During winter, the temperature in underground parking spaces is relatively higher than the outside air temperature. By recovering waste heat from the engines of parked vehicles and exchanging it with a water storage tank in the underground mechanical room, this heat can be used to decrease the domestic hot water load. To assess the enhancing effect, with measured temperature of the underground parking space, building with the harvesting system is simulated for winter season. Firstly, existing literature were reviewed to investigate methodology for recovering waste heat. Secondly, information of target residential building, and condition of the simulation are explained. After that, simulation is conducted to estimate the effect of the waste heat recovery system on the building, and the result is discussed. This research is expected to found research basis for the waste heat recovery in the basement parking space of residential building.

Performance analysis of air-side indirect evaporative cooling air-conditioning system under mixed operating mode in data centers

Yunran Min[1], Zhibo Lei[2], Dongye Fan[3]
[1]Jimei University, China, People's Republic of; 2Fujian Province Key Laboratory of Energy Cleaning Utilization and Development, Xiamen, China; [3]China Academy of Building Research, Beijing, China

Utilizing natural cooling sources to either partially or entirely substitute mechanical cooling is crucial for data center (DC) energy saving. The air-side indirect evaporative cooling (IEC) air-conditioning system, integrates the cooling effects of outdoor unsaturated air and a direct expansion refrigeration cycle (IEC-DX), has emerged with widespread applications in DCs across different climate zones.

Existing performance evaluations of IEC-DX are all based on rated cooling capacity or simplified empirical formulas of cooling efficiency, neglecting the effects of dynamic operating conditions. In this paper, a physics-based mathematical model of IEC-DX was established to describe the interactive heat and moisture transfer processes among spraying water, refrigerant, return air and outdoor air. After verification by experiments, the energy saving performance was investigated by simulations under different operation conditions. Results showed that the coefficient of performance (COP) of DX in the integrated system was improved due to the reduction of condensation temperature. However, it decreases rapidly in high temperature and high humidity climates. When the outdoor air temperature exceeds 32℃ and the relative humidity exceeds 85%, the COP of IEC-DX is lower than that of the standalone mechanical cooling system. The optimal outdoor air flow rate under mixed operating mode is higher than the optimal value when IEC operates alone. With the outdoor air temperature increases from 24℃ to 32℃, the optimal outdoor air to return air flow rates ratio of IEC-DX decreases from 1.1 to 1.03. The results of this study can provide guidance for upgrading the design and operation strategies of IEC-DX systems, realizing the efficient synergy of natural and mechanical cooling sources for DCs.

【FUTURE 05: Demand Flexibility and Electrification】

10th December, 1:30 pm ~ 2:45pm

Session Chair: Habin Jo, Chonnam National University

Session Chair: Andrew Marian Zajch, Osaka University

Electricity demand disaggregation for building energy management

Takeshi Okada[1], Yohei Yamaguchi[2], Yoshiyuki Shimoda[2]
[1]TAISEI CORPORATION, Japan; [2]Osaka University, Japan

Time-series electricity demand data are valuable for building operating conditions and energy management. However, a detailed demand analysis requires significant time and resources. Quantifying energy demand, particularly for specific equipment and end use, presents challenges that increase costs and require additional measurements. To address this, load disaggregation techniques have been developed to decompose the total energy demand of a time series into individual equipment or end use. The load disaggregation method can be broadly divided into methods that use high-temporal-resolution data (e.g., 1-min intervals), such as harmonic data, and simple methods that use low-temporal-resolution data (e.g., 30-min intervals) obtained from smart meters. Considering their versatility and applicability to energy management, this study reviews the progress and challenges of simplified load disaggregation methods and explores their potential for energy management applications. This review suggests that disaggregation methods can be applied effectively to various building types. In addition, examples of quantitative and qualitative energy management evaluations were provided, and it was found that equipment unit resolution was necessary for quantitative evaluations. In addition, it evaluates the energy management that can be performed with previous disaggregation using actual office data, and the issues that must be addressed.

Uncertainty analysis of building energy flexibility in providing day-ahead demand response

Xiaoyu Jia[1], Yiqun Pan[2], Zhizhong Huang[3], Xiaolei Yuan[4]
[1]School of Mechanical Engineering, Tongji University, Shanghai, China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA; [3]Sino-German College of Applied Sciences, Tongji University, Shanghai, China; [4]Department of Mechanical Engineering, School of Engineering, Aalto University, Espoo, Finland

Assessing the potential of building energy flexibility is a key issue for decision-makers at the operation level. However, the weather forecast, uncertain building cooling load, and sensor noises are process uncertainties for energy use prediction to quantify building energy flexibility, which has been overlooked in most studies. To fill this gap, this study proposed a novel way to implicitly explain the influence of process uncertainty on quantifying building energy flexibility. Firstly, the detailed building energy simulation software, TRNSYS was utilized to simulate power consumption patterns under 5 basic controllers, aiming to alleviate the impact of inefficient heating, ventilating, and air conditioning (HVAC) system control. Secondly, the energy use model was developed by comparing several explicit models. The results indicate that the second-degree polynomial model performs best, with a CV-RMSE of 2.088%, and its relative error distribution passes the Shapiro-Wilk normality test. Thirdly, the uncertainties of weather forecasts, sensor noises, building cooling load prediction results, and building energy use models were characterized and propagated through the energy use model. The contributions of each parameter to the uncertainty of building energy flexibility were compared. Lastly,

the effect of room temperature setpoint on the uncertainty was researched. It is found that when increasing the setpoint increased by 1 ℃ in the summer season, the uncertainty can be reduced by 21.16%.

Evaluation of a Method to Increase the Efficiency of Groundwater Heat Pump in Japanese Traditional Residential Communities, as a Part of Net-zero Energy Community Proposal

Pei LIU, Chiemi IBA
Kyoto University, Japan

Kyo-machiya are traditional Japanese residences in Kyoto. In accordance with the Japanese national carbon neutralization goal and city ordinance on Kyo-machiya preservation and regeneration, an energy-saving renovation plan for achieving a netzero energy community for Kyo-machiya is under discussion. Their distinct individual situations make it difficult to convert each dwelling into a zero-energy house. However, focusing on a community scale provides certain advantages. One of these methods is the use of underground heat. Most Kyo-machiya have a shallow well, and it is feasible to harvest and distribute heat through the well water using a groundwater heat pump without a high initial excavation cost. However, the heat pump efficiency decreases with a decrease in water temperature during system operation. In previous research, a drainage pump was used to drain cold water out of the well to increase the heatreplenishing speed and efficiency of the heat pump. However, owing to the small amount of water storage, the drainage pump had to work intermittently, which limited the improvement. This study proposes a new strategy for recharging warmer well water from another well where no heat pump is operating, to the heat harvest well. The simulation shows that it can effectively improve system performance and sustain a longer duration of system operation.

Energy Saving Potential of a Tankless Hybrid Heat Pump System in Residential for Individual Space Heating and Domestic Hot Water

Suyeon Hong, Soo-Jin Lee, Beom-Jun Kim, Seheon Kim, Jae-Weon Jeong
Hanyang university, Korea, Republic of (South Korea)

This study aims to propose a tankless hybrid heat pump system utilizes a gas boiler as an auxiliary heat source. To evaluate the energy-saving potential of the proposed system, a comparative analysis was conducted between a traditional condensing gas boiler system and the proposed system. The comparison focused on the primary energy consumption required to maintain indoor temperature and domestic hot water supply temperature in a target building, simulated over a four-month winter period, including conditions with low outdoor temperatures. The primary energy consumptions of the proposed system and the reference system are estimated using an engineering equation solver with each component model. As a result, the proposed system showed a total energy savings of 14.6% compared with the reference system.

Poster Session

Monday-Tuesday, 9th–10th December, 1:00pm ~ 1:30pm

A Compact, Battery-Operated Solution for PMV Measurement

Eisuke Togashi[1], Satoru Yamaguchi[2]
[1]Kogakuin University, Japan; [2]EleBees

This study presents the development of a PMV (Predicted Mean Vote) measurement and recording device designed with the specific purpose of evaluating indoor thermal environments. The accurate measurement of temperature, humidity, radiant temperature, and velocity is of great importance for the assessment of indoor environments. However, conventional measuring devices are frequently large, expensive, and limited by power consumption, which presents a significant challenge in this field of study. To address these challenges, a compact device capable of long-term, battery-powered operation was developed. The device incorporates a multitude of sensors, including those for dry-bulb temperature, relative humidity, globe temperature, velocity, and illuminance, which employ communication protocols such as I2C, UART, and SPI. The device utilizes custom-designed circuitry developed to accurately measure low velocities (below 1.0 m/s). The device's power consumption was optimized through the integration of a DC/DC converter and a low-power sleep mode for the wireless communication module, enabling uninterrupted operation for over two weeks when measuring every 15 minutes.
A simple wind tunnel was constructed for the purpose of validating the accuracy of the velocity sensor. The results demonstrated that the mean error did not exceed 0.1 m/s across the tested velocity range. The device's compact dimensions and cost-effective design, enabled by the use of printed circuit board assembly (PCBA) services, make it a promising tool for high-density measurements in indoor environments. Comprehensive circuit diagrams, software components, and additional information are made available online, supporting continuous improvement by the open-source community. This study highlights the potential of open-source hardware in advancing environmental monitoring technologies and invites readers to contribute to ongoing development efforts.

Proposal for a Method of Integrating Building Equipment and BIM Information Using IFC

Yuuhi Baba, Motoi Yamaha, Aya Yokoe
Chubu University, Japan

Recently, BIM has become increasingly popular, and 3D information on buildings is now created during the design phase. However, the transition from BIM data to energy simulation has been infrequent, partly due to the need for detailed equipment system information. We have examined how to integrate equipment information into BIM and deploy it for energy simulation and maintenance management.
The performance information of equipment required for simulations, etc., is provided in the form of equipment tables at the design stage. Creating data that has both 3D data of the building and information on equipment is considered to facilitate input to simulations and maintenance management of equipment. In this study, BIM data created at the design stage is exported to IFC, and a method for integrating this data with equipment information obtained from equipment tables is investigated. Since the IFC Entity of equipment exported from several BIM applications is derived from IfcProduct, it was decided to associate equipment information with this attribute. The equipment in the equipment tables and the equipment in the IFC file are matched by equipment number, and the equipment

information is associated as a PropertySet. Equipment numbers are sometimes set as a PropertySet and sometimes as the name of the equipment entity, so we considered how to handle both.
As a result of the study, it was possible to integrate the 3D data of the building and the equipment information as long as the equipment table format was the prescribed one. This study suggests that simulation data can be derived from this integrated information. However, due to the variability in equipment table formats, further research is needed to develop methods that accommodate all formats.

A Study on the Energy-Saving Effects of Rooftop Greenhouses with the Application of Low-Emissivity Coatings

Subin Song[1], Nari Yoon[2], Seonghwan Yoon[1]
[1]Department of Architecture, Pusan National University, Pusan, Korea; 2Department of Architecture, Ajou University, Suwon, Korea

Due to climate change, crop production is expected to decline, leading to a gradual increase in indoor cultivation. This study focuses on the thermal and optical properties of various transparent envelope materials to analyze the energy performance of greenhouses. In temperate climates like South Korea, optimizing greenhouse envelopes is crucial for enhancing energy efficiency and supporting crop growth. The materials examined include PE film, double glazing, and Low-E glass. Low-E glass was found to enhance insulation, reducing heating loads while increasing cooling demand due to heat retention. However, the flip-frame Low-E system, which allows for seasonal adjustments, reduced heating loads by 28% without increasing cooling demand, while maintaining visible light transmittance above 80%. Furthermore, installing greenhouses on rooftops provides the additional benefit of reducing building energy consumption by 14% to 19% in single-story buildings. This research emphasizes the importance of selecting appropriate transparent envelope materials for energy-efficient greenhouse design and offers practical solutions to enhance the energy performance of both greenhouses and the buildings they are part of.

A Sustainable Future Blueprint: Rethinking Forecasting Carbon Emission Trends in Shanghai's Construction Industry

Qicong Dong[1], Yiqun Pan[2], Zhuoqun Xing[1], Zhizhong Huang[3]
[1]School of Mechanical Engineering, Tongji University, Shanghai, 201804,China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15217, USA; [3]German College of Applied Sciences, Tongji University, Shanghai, 201804, China

Many studies have shown that the carbon emissions of the construction industry contribute significantly to achieving the carbon peaking goal by 2030 and the carbon neutrality goal by 2060. This study aims to predict the multi-path carbon emission trends of the construction industry in Shanghai from 2020 to 2060 and estimate the carbon emissions under different scenarios in the target years. First, the carbon emissions of Shanghai from 2005 to 2019 were statistically analyzed. Based on the KAYA equation, the influencing factors of carbon emissions from building construction, public building operation, and residential building operation were decomposed. On this basis, a hybrid carbon emission influencing factor evaluation system was constructed using the random forest-SOBOL algorithm to identify variables that need to be controlled with priority. Afterward, scenario analysis was conducted to construct four carbon emission scenarios and 12 carbon emission paths through the random walk model and Monte Carlo sampling method. This study provides a scientific reference for subsequent policy formulation.

An Experimental Study on Thermal Performance of Insulation Materials for Enhancing Building Energy Efficiency

Ji Ho Park[1], Yul Ho Kang[2], Hae Eun Song[1], Sang Moo Woo[1], Dong Hyun Shin[1], Hyo Kyung Sung[1], Young Chull Ahn[1]
[1]Department of Architectural Engineering, Pusan National University, Korea; [2]Research Institute of Industrial Technology, Pusan National University, Korea

In response to the growing importance of energy-efficient buildings due to climate change, this study analyzed the insulation performance of building materials beyond traditional thermal conductivity measures. While thermal conductivity is a common indicator, it often does not accurately predict surface temperature differences in real-use conditions, especially for composite materials like vacuum insulation panels (VIPs). This study confirmed that, under four different air temperature conditions, all insulation materials except vacuum insulation panels (VIPs) show a linear inverse relationship between surface temperature differences and design thermal conductivity. VIPs showed significant heat loss at the edges due to thermal bridges, leading to lower temperature differences at the edges compared to the center. This study not only reinforces previous research on the characteristics of vacuum insulation panels (VIPs) but also aims to provide foundational data that could enhance industry standards for insulation material performance.

Analysis of air side fouling and cleaning characteristics of air conditioning heat exchanger

Dong Hyun Shin[1], Yul Ho Kang[2], Hae Eun Song[1], Sang Moo Woo[1], Ji Ho Park[1], Hyo Kyung Sung[1], Young Chull Ahn[1]
[1]Pusan National University, Korea; [2]Research Institute of Industrial Technology, Pusan National University, Korea

This study is an experimental study that analyzes the fouling and cleaning characteristics according to the shape and gap of the fins of the air-side heat exchanger. As the air-side heat exchanger is used for a long time, particulate matter of external dust adheres to the surface. This reduces the heat exchange area and increases the thermal resistance, which deteriorates the performance of the heat exchanger. To prevent the performance degradation due to fouling, the heat exchanger must be washed with water periodically. In addition, to prevent dust adhesion due to residual water particles after washing, the operation must be resumed only after it is completely dried. In this study, an accelerated fouling test is performed to analyze the dust adhesion characteristics of the fin-tube heat exchanger and to investigate the cleaning performance through a water washing-drying cycle. The performance degradation due to fouling was indirectly estimated through the pressure drop, and the fouling was performed three times for 60 minutes, cleaning for 10 minutes, and drying for 10 minutes each.

Characterization of the Amplification Factor for Intermittent Air-Conditioning Loads in Office Buildings

zou quan
Hunan university, China, People's Republic of

The choice of peak load on the design day directly affects the accuracy of building cooling load calculations and the efficiency of building energy consumption, Thus, accurate peak load calculations are crucial in office buildings. Intermittent air-conditioning is widely used because it meets practical scenarios, but its peak load calculation relies on the indirect calculation of continuous air-conditioning peak load, which is not accurate enough. Therefore, this study attempts to apply the heat balance method to intermittent air-conditioning system (HBI) in an office building to calculate the hourly cooling load and compare it with the standard test case of ASHRAE 140-2020. The results show that the new model has an annual load deviation of 5.9% and -3.6%, which meets the standard requirements. furthermore, the new model for calculating hourly loads of intermittent air-conditioning can pick peak loads more efficiently than the traditional method and provides a more reliable basis for accurate air-conditioning design and engineering application.

Comparison of residential thermal comfort and window operation between Brisbane and Hangzhou homes

Yiyan Lv[1], Shuqin Chen[1], Jingdong Wu[1], Hao Lei[2], Jing Xiong[3], Yao Xiao[3], Thomas Parkinson[3], Jungsoo Kim[3]
[1]College of Civil Engineering and Architecture, Zhejiang University, Hangzhou, China; [2]School of Public Health, Zhejiang University, Hangzhou, China; [3]IEQ Lab, School of Architecture, Design and Planning, The University of Sydney, Australia

The thermal sensation and window operation behavior of occupants in residential buildings have a large impact on building design and energy calculations. This paper investigates the thermal comfort and the window operation behavior of residents in two cities, Brisbane and Hangzhou, which are both located in the humid subtropical climate zone. The results of the questionnaire and measured data show that the thermal sensations of the residents in the two cities are similar, with an acceptable temperature range of 16.3-28.6 °C. This is 5 K wider than the range specified by the adaptive model in ASHRAE-55. Window operation behavior of Brisbane residents is strongly related to outdoor temperature. In contrast, the window operation behavior of Hangzhou residents in bedrooms is not strongly associated with outdoor temperature, probably due to the habitual desire for fresh air. The findings of this research could better inform schedule and behaviors of residents in building design and energy simulation tools.

Human-Centered Generative AI Framework in Intelligent Construction: A Case Study on Furniture Manufacturing Design

Zeyin Song[1], Jinghan Qiu[2], Hao Zheng[3], Shu Xiao[1]
[1]Institute for Advanced Architecture of Catalonia, Spain; [2]Tongji Uiniversity, Shanghai 200092, China; [3]Department of Architecture and Civil Engineering, City University of Hong Kong, HKSAR, China

This study introduces a human-centered Generative Artificial Intelligence (GAI) design approach, emphasizing its application in the field of intelligent architecture, with a particular focus on furniture manufacturing design as a case study. This method integrated stable diffusion technology and

leverages optimization algorithms to create designs that not only meet structural requirements but also accurately reflect human preferences. Initiated by user-generated 2D sketches, implicit features were captured through technologies such as stable diffusion, resulting in designs that align with the user's unique style. The outputted designs underwent topological optimization to enhance material performance and structural stability. Subsequently, modifications and production were seamlessly executed through the robotic arms. The results demonstrated that the proposed method effectively provides users with a diverse range of stylistic de-signs, allowing for easy modifications based on text prompts and manuscripts. This study contributed to optimizing the architectural design workflow and providing a structured solution for handling AI-generated outputs.

Investigating the relationship between air temperature and urban morphology factors using a long short-term memory network model

Chengliang Fan[1,2], Binwei Zou[1], Mo Wang[1], Xiaoqing Zhou[1,2]
[1]School of Architecture and Urban Planning, Guangzhou University, China; [2]State Key Laboratory of Subtropical Building and Urban Science, Guangzhou, China

The rapid urbanization and recurrent heatwaves pose significant threats to urban microclimates. While extensive research has delved into the quantitative links between urban form and heat island effects at the citywide level, fewer studies have scrutinized these relationships on a finer block-by-block scale. This study introduces a Long Short-Term Memory Network (LSTM) model aimed at forecasting the influence of urban morphology factors on air temperature within distinct Local Climate Zone (LCZ). We quantified and characterized the effects of spatial morphological attributes on air temperature. Our findings indicate that incorporating historical data spanning three time steps yields the most accurate air temperature predictions, achieving an R^2 value of 0.9747. Notably, urban morphology factors outweighed land cover type in influencing air temperature, with the sky view factor (SVF) emerging as the most influential, followed by aspect ratio (AR) and pervious surface fraction (PSF). Interestingly, land cover type was found to exacerbate warming more than building type, and low-rise districts demonstrated greater resilience to heatwaves due to their mitigated temperature increases. These insights offer valuable knowledge on the interplay between urban form and microclimate, underscoring their crucial role in shaping climate-responsive urban planning strategies.

Long-Term Missing Value Imputation for Building Energy Consumption Data Based on BDI - VMD – BiLSTM

<u>Zhuoqun Xing</u>[1], Yiqun Pan[2], Yiting Yang[3], Zhizhong Huang[4]
[1]School of Mechanical Engineering, Tongji University, Shanghai 201804, China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA; [3]Department of Mechanical & Aerospace Engineering, Syracuse University, Syracuse, NY13244, United States; [4]Sino-German College of Applied Sciences, Tongji University, Shanghai, China

The prevalence of missing values (MVs) in building energy consumption (BEC) data will seriously affect the use of BEC data in areas such as analysis, forecasting, and dispatching. The paper proposed a bi-directional imputation (BDI) method that utilizes temporal information before and after the MVs. Initially, the known data is decomposed using Variational Mode Decomposition (VMD) to extract underlying patterns. Subsequently, each decomposition pattern was estimated using a bi-directional long short-term memory (Bi-LSTM) model and weighted by the BDI to obtain the predicted values of the MVs. Experimental results demonstrate the superior performance of the proposed method in long-term MVs imputation compared to traditional statistical-based imputation methods and baseline

models. The models using the VMD method showed significant improvement in prediction and superior central tendency and dispersion of the error distribution (ED).

Low carbon design: Optimization of building envelope based on a dynamic life cycle assessment model

Changqi Li[1], Yiqun Pan[2], Shengyang Hu[1], Zhizhong Huang[3]
[1]School of Mechanical Engineering, Tongji University, Shanghai, 201804, China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15217, USA; [3]German College of Applied Sciences, Tongji University, Shanghai, 201804, China

More than one-third of global carbon emissions are generated from the materialization and operational stages of buildings. Mitigating carbon emissions throughout the building life cycle is crucial for achieving sustainable development. Previous studies adopt a static grid emission factor to assess buildings' life cycle carbon emissions, ignoring the dynamic changes of the future electricity mix. This study aims to explore the impact of considering dynamically changing grid emission factors on the optimal parameters of the building envelope. First, a dynamic life cycle assessment (LCA) model considering dynamic grid emission factors is established to predict the life cycle carbon emissions of buildings. Second, a multi-objective optimization method is proposed to minimize life cycle carbon emissions while trade-off its life cycle costs. Finally, a prototypical office building located in Shanghai is selected to perform the analysis and optimization. The result indicates that ignoring the dynamic changing of grid emission factors will lead to overestimating the operational carbon emissions by 64.8%, which in turn will result in an over-insulated design of the envelope. This study illustrates the importance of using the dynamic LCA model in selecting the optimal design parameters facing low carbon design of building envelope.

Multi-objective Optimal Operation Strategy For Photovoltaic Systems In Logistics Parks Concerning Climate Impact

Kai Peng[1], Wenxuan Zhao[1,2], RongPeng Zhang[1,2,3]
[1]School of Architecture and Planning, Hunan University, Changsha, China; [2]Hunan Key Laboratory of Sciences of Urban and Rural Human Settlements in Hilly Areas, Hunan University, Changsha 410082, China; [3]Hunan International Innovation Cooperation Base on Science and Technology of Local Architecture, Changsha 410082, China

Solar power is one of the most promising renewable resources for generating electricity and alleviating building energy demands. Logistics parks, with their low-rise buildings and extensive rooftops, offer significant advantages for solar energy utilization via rooftop photovoltaic. However, limited research has been conducted on proper operational principles and optimal control strategies for photovoltaic (PV) systems for logistics parks, particularly regarding the impact of climate conditions and mismatch between electricity generation and actual building loads. This study therefore proposes an optimal operation strategy of PV panels for logistics parks across multiple climatic regions using a multi-objective optimization method. The optimal azimuth and altitude angles are identified under four panel adjustment strategies, i.e., annual fixed, semi-annual, seasonal, and monthly adjustments. The proposed strategy is tested and validated in an actual logistics park of 5500m2. The results show that both climatic factors and the frequency of adjusting PV panels significantly affect optimization benefits. In climate zones with high solar radiation, monthly adjustments perform the best compared to traditional fixed installations. Self-consumption can be increased by 82.44% −359.04% and reduce electricity costs by 9.26% −17.02%. This study can provide valuable data insights and future

directions for optimal operation for photovoltaic systems in large-scale logistics parks.

Optimization and prediction study of design factors for school classrooms based on energy consumption and comfort

Chen Zhengshu, Cui Yanqiu, Ding Xin, Yang Haoran
Shandong Jianzhu University, People's Republic of China

Classrooms demand high standards of lighting and thermal comfort. Particularly in regions experiencing cold winters and hot summers, enhancing indoor light and thermal comfort often necessitates active measures such as heating and cooling, which significantly increase building energy consumption. Therefore, effectively reducing energy consumption while improving indoor light and thermal light is an urgent issue. This study employs a data-driven approach integrating optimization, evaluation, and prediction for the performance of two types of classroom. By applying this approach to a case study of a teaching building in cold region, aimed at augmenting light and thermal comfort while curtailing energy consumption, the study optimized the classroom form, fenestration, and thermal performance. This approach enhances the optimization potential of classroom design factors and provides references for designers to conduct assessments of indoor thermal and light comfort.

Optimized Microgrid Operation with Model Predictive Control: Balancing Energy Storage and Electricity Trading Opportunities

Shengyang Hu[1], Zhuoqun Xing[1], Changqi Li[1], Zhichao Liu[1], Yiqun Pan[2], Zhizhong Huang[3]
[1]School of Mechanical Engineering, Tongji University, Shanghai 201804, China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA; [3]Sino-German College of Applied Sciences, Tongji University, Shanghai, China

In response to the growing integration of renewable energy and the associated challenges of grid stability, this paper introduces an model predictive control (MPC) strategy for energy storage systems within microgrids. The volatility of wind and solar energy complicate microgrid operations, necessitating precise and responsive control mechanisms. We develop a multi-time scale scheduling approach that leverages MPC alongside battery energy storage to stabilize microgrid performance. Using real-world data from the University of California, San Diego, we forecast microgrid loads and photovoltaic output through a hybrid Long Short-Term Memory-Transformer model, enhanced by transfer learning. By incorporating rolling adjustments for real-time price predictions, we enhance our control strategy's adaptability to market fluctuations. This approach enhances operational efficiency and reduces costs by managing energy storage, particularly during peak price periods, highlighting its potential for advanced energy scheduling in complex market environments.

Quantitative Evaluation of Calendarization in CPM Using Monthly Energy Consumption Data in Korea

Hye Gi Kim, Seung Eon Lee, Deuk Woo Kim
Korea Institute of Civil Engineering and Building Technology, Korea, Republic of (South Korea)

Change-Point Model (CPM) in building energy analysis often utilize monthly data due to its practicality and accessibility. However, discrepancies between actual and billed consumption compromise CPM reliability, particularly in Korean buildings where multiple meters with diverse billing periods are prevalent. This study evaluated the impact of calendarization on CPM accuracy across 50,345 South Korean public buildings. Results demonstrated an average 19% increase in the coefficient of determination (R^2) post-calendarization. These findings emphasize calendarization's significance as a crucial preprocessing step in building energy analysis, especially for large-scale studies informing energy efficiency policies and retrofit strategies.

Simulation Analysis of Energy Consumption in Office Buildings Based on Aspect Ratio in South Korea

Juhee Nam[1], TaeCheol Lee[1], JungHo Jeon[2], SeongHwan Yoon[3]
[1]Department of Architecture, Pusan National University, Busan, Korea; [2]2Department of Architectural Engineering, Pusan National University, Busan, Korea; [3]3Department of Architecture/Institute for Future Earth, Pusan National University, Busan, Korea

In the early design stage, shape of the building, window to wall ratio, aspect ratio, building orientation, etc. play a pivotal role in determining building energy efficiency. This study explores building energy-savings measures based on such design factors in the early design stage for improving energy performance of office buildings. Taking into account the predominant building shapes of office buildings in Korea, U, rectangle, plus (+), and H shapes were taken into consideration for energy simulation. The thermal transmittance (U-value) was determined based on Korean energy-saving design standards for buildings. The results of the study show that the annual cooling load increases as the window-to-wall ratio increases and the cooling load distribution was found to increase in descending order of U, rectangle, plus (+), and H shapes. In terms of building orientation, U and H shaped buildings show similar energy trends when oriented at 0° and 135°, while rectangle and plus shaped buildings showed an opposite trend as the building envelope area for different building shapes changes based on orientation. Therefore, the simulation results show that the building envelope area and effective window area for different building shapes play a crucial role in optimizing building energy consumption despite the same floor area.

Simulation-based estimation of optimal equipment capacity and effect of suppression operation for VRF systems

Motoi Yamaha, Yuhi Baba, Aya Yokoe
chubu university, Japan

Variable Refrigerant Flow (VRF) system is popular HVAC system in Japan especially for small or middle size buildings. Since VRF system is a packaged machine containing heat pump, fans, filters and controllers, energy saving operation adopted to the load situation is difficult to apply comparing to central HVAC system. The study focuses on evaluating the effectiveness of optimum design equipment capacity and implementing suppression operations which limit electricity consumption under set value

in VRF systems. The goal is to achieve energy savings while maintaining indoor comfort.
The study uses EnergyPlus with the VRF module's physics based model, which can control the compressor's rotational speed. The simulation is conducted on a model of an school building. As VRF systems tend to have excessive design capacities, reduction rates of 0%, 20%, and 30% were set for the actual installed equipment capacities, and the energy consumption and indoor temperature during the cooling period were compared under both normal and suppression operations.
Higher reduction rates resulted in lower energy consumption. At 20% and 30% reduction rates, suppression operations led to lower energy consumption compared to normal operations. No significant difference in indoor temperature between normal and suppression operations, indicating that comfort can be maintained even with suppression. Suppression operations were more effective during high load conditions. Annual energy savings from suppression operations increased with higher capacity reduction rates (5.8%, 9.9%, 12.4%).
The study confirms that appropriately setting equipment capacity and implementing suppression operations can reduce energy consumption by approximately 20% without compromising indoor comfort. Avoiding over-design and setting the correct equipment capacity enhances the effectiveness of suppression operations and achieves greater energy savings.

Study on the operation of series coil air conditioning system when sensible heat load is decreased.

Kasumi Yamamura
Nagoya City University, Japan

In recent years, room sensible heat loads have been decreasing due to improved building insulation and lower internal heat generation caused by the use of LED lighting fixtures. Thus, the proportion of the latent heat load to the total heat load has increased, and this has caused the problem that conventional air conditioning systems are inadequate to handle the latent heat load. Effective solutions to this problem exist at present, but they have disadvantages such as the need for warmth and the complexity of the system. Therefore, this study focuses on a multi-coil air conditioning system that does not require heat and can handle the load only with chilled water coils. In particular, we focus on series coil air conditioning systems, which have few examples of actual implementation or operational studies under the recent conditions of reduced indoor sensible heat load. We constructed a model of a series coil air conditioning system and a single coil air conditioning system with TRNSYS and simulated the period (April to November). As a result of the simulation, the series coil air conditioning system was able to maintain the room environment at the setpoint for both room temperature and room relative humidity. However, the single coil air conditioning system was able to maintain the room temperature at the setpoint, but the room relative humidity was unable to maintain the setpoint and became larger. In addition, series coil air conditioning systems consumed more energy than single coil air conditioning systems. These results indicate that the series coil air conditioning system processes the room sensible heat load and the total heat load separately, so both loads are easily processed normally. Therefore, the series coil air conditioning system can provide a more comfortable indoor environment for people.

Study on the Spatial Distribution Characteristics of Traditional Villages in Jiangnan Area

Bingqing Yu, peng Zhang
Tongji University

In recent years, national strategies such as beautiful countryside and rural revitalisation have been continuously promoted, and the protection and use of traditional villages have increasingly become a hotspot of social concern. This paper takes the existing 1631 traditional villages in Wu, Gan and Hui dialect areas as the research object, uses ArcGis and Excel software and data statistical methods to analyse the spatial distribution, explores the relationship between the distribution of traditional villages and elevation and hydrology, analyses the closest point index, imbalance index, distribution of the degree of concentration of the villages and the kernel density analysis, and focuses on analysing the relationship between the different elevation of the mountains and hills, the direction of the slopes, the gradients The idea of "back mountain", "face screen", "face water" and "water ring" in traditional feng shui is used in the selection of village sites under the geographical and hydrological conditions of the region.

The non-fixed power balance between two navigation strategies; the demonstration by the controlled experiment.

Takanori Nanahara, Sihwan Lee
Nagoya University, Japan

During a wayfinding process, people use several strategies to make their decision on path selection. Environmental and knowledge-based requisites of each strategy have been investigated. However, the choice between two strategies has not been explicitly considered, particularly when the two strategies lead people toward opposite directions. This study shows that the power balance between the two strategies, the direction- and the floor-strategy, is not fixed. The authors conducted an experiment in which subjects were asked to take one way out of two at an intersection where one or both of these two strategies were available, and the distance from the intersection to the staircase (i.e., the spatial requisite of the floor-strategy) was varied. The strategy selection and the look-around behaviour at the intersection by the subjects were recorded. Results showed that when only one of the strategies was available, a significant number of subjects used that strategy. As for the floor-strategy, its usage declined as the distance to the staircase increased. In situations where the two strategies were conflicted, no significant difference between the usage of the two strategies was shown regardless of the distance to the staircase. However, the subjects who used the floor-strategy were looking around more than those who did not. From these results, it is shown that the hierarchy between the two strategies are not uniform; rather, it is influenced by whether they found or not the staircase.

A bi-level scheduling strategy for an integrated energy system with the orderly charging/discharging of electric vehicles

Zhichao Liu[1], Yiqun Pan[2], Zhizhong Huang[1], Xiaolei Yuan[3]
[1]School of Mechanical Engineering, Tongji University, Shanghai, 201804, China; [2]School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15217, USA; [3]Department of Mechnical Engingering, School of Engineering, Aalto University, Espoo, Finland

As the number of electric vehicles (EVs) is increasing rapidly, it is necessary to consider EVs to cooperate with the integrated energy systems (IESs) for orderly charging and discharging (OCD). In order to fully utilize the power batteries of EVs, this study proposes a bi-level model to achieve the cooperative optimization of the OCD and the IES. The upper level of the model aims at minimizing the operating cost of the system, and the lower level aims at minimizing the net charging cost of any EV during the cooperative period. In this case, the EVs make self-decision through the price signal released by the system. The bi-level model proposed in this study is transformed into a single-level mixed-integer nonlinear programming model by the Karush-Kuhn-Tucher condition. Finally, by comparing the two systems considering the OCD of EVs or not, this study found that it is effective in reducing the operating cost of the system, while the EV owners can reduce the charging cost by participating in the system cooperation. Overall, the bi-level model proposed in this study is able to effectively reduce the system operating cost by fully utilizing the internal energy storage resources of EVs, and realize the mutual benefits of EV owners and the system.

Simultaneous presents faults detection by using Diagnostic Bayesian Network in Air Handling Units

Ziao Wang, Chujie Lu, Martin Mosteiro-Romero, Laure Itard
Department of Architectural Engineering and Technology, Delft University of Technology, Delft, the Netherlands.

Energy waste in buildings can range from 5% to 30% due to faults and inadequate controls. To effectively mitigate energy waste and reduce maintenance costs, the development of Fault Detection and Diagnosis (FDD) algorithms for building energy systems is crucial. Diagnostic Bayesian Networks (DBNs), as graphical probability models, are particularly useful in scenarios where high-quality data is not always available. While many studies have focused on single fault detection using DBNs, the occurrence of multiple simultaneous faults is common, yet the versatility of DBNs in handling such cases is rarely explored. This study adapts a DBN, initially designed for single fault diagnosis, to perform simultaneous fault diagnosis Experiments were conducted on an air handling unit (AHU) in the Netherlands, using implemented simultaneous faults to test the model. The results suggest that the DBN can detect both single and multiple faults effectively.

Introducing Causality to Symptom Baseline Estimation: A Critical Case Study in Fault Detection of Building Energy Systems

Chujie Lu, Ziao Wang, Martín Mosteiro-Romero, Laure Itard
Department of Architectural Engineering and Technology, TU Delft, the Netherlands

Fault detection and diagnosis (FDD) provides several interrelated benefits, including reducing energy waste, enhanced operational efficiency, and maintaining indoor comfort. The initial step in FDD is to detect deviations from normal or expected operation. However, establishing a reliable baseline can be challenging, especially when there is a lack of sufficient system documents or when complex control strategies are involved. This study investigates three feature selection methods for the baseline estimation: expert knowledge-based, correlation-based, and causality-guided, using heating coil valve control estimation as an example. These methods were tested in an office building in the Netherlands. The results show that while the correlation-based method achieved the best estimation, it may lead to false negatives due to features with reverse causality. This study aims to emphasize the necessity of causal analysis in the baseline estimation to achieve reliable FDD in buildings.