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Indoor Environmental Quality monitoring through automated mobile sensing

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An expected benefit of the Internet of Things (IoT) in buildings will come from an improved ability to monitor indoor environment quality (IEQ) in ways that lead to actionable insights. For instance, understanding CO_2 concentrations in buildings is important, as several recent studies suggest that high levels of the gas may have negative effects on our cognitive performance. Yet there are challenges to measuring CO_2 in a reliable and comprehensive manner. Also, other indoor air pollutants such as ozone (at low concentrations can purify the air and give a feeling of “mountain-freshness,” but at high concentrations may harm human health), can be expensive to measure in indoor spaces and have not been traditionally monitored. Indeed, a challenge in creating highly-granular IEQ monitoring is the cost of installing and maintaining arrays of sensors throughout a building.

From static to dynamic: keep moving!

The goal of this work is to explore an innovative method to monitor buildings using the latest sensing and communicating technologies. This requires rethinking about current within building sensing approaches. Generally, there are two types of approaches. The first approach is using “sensors with fixed locations”. Here, sensors are typically embedded in large equipment such as air conditioning and ventilation systems such as humidity and temperature sensors or fixed on walls and appliances such as light sensors and smoke detectors. These sensors typically cannot be transported easily from one location to another. The advantage of this approach is that it eases the job of data visualization and analytics mainly because location information does not need to be updated once sensors are deployed. But this limits the capability of sensing irregular or infrequent events that may happen outside the network sensing scope. The second approach relies on “sensors with adaptable locations”, often performed by a human carrying the sensor set from one location to another. While this allows a comprehensive evaluation of the indoor environment, it is often very time-consuming and labour-intensive. The person evaluating the IEQ need to survey the spaces while also recording the locations where the measurements are taken.

The question that we would like to answer in this work is: can we create an automated mobile sensing system that can adaptively adjust its measurement locations while doing this on a day-to-day or even hour-to-hour basis? Indeed, the benefits are numerous with such an approach. For instance, one can dramatically reduce the capital costs associated with expensive sensors, thus creating scalable and continuous sensing maps that can enable more interesting discoveries. Also, if there are some abnormal events, such as gas leakage or a fire emergency, we would expect the important signal to be captured by the automated mobile sensing system to get real-time information and form contingency plans.

A B C

FIGURE 1 Three sensing paradigms inside buildings: (A) Static sensor network; (B) Human operated sensor; and (C) Automated mobile sensing

Location, time and data

Indeed, to create such application requires tackling a range of challenging issues. For example, how can we transport the sensors to designated locations? What is the shortest path? How to navigate through the dynamic and complex indoor spaces filled with people? Because the measurements are taken sequentially, how do we account for temporal difference between two measurements taken at two different locations? Lastly, how can we use this information to monitor the space, identify operational inefficiency and even respond to emergencies? Successfully answering these questions would mean that we can enable a new sensing paradigm in smart buildings to create highly-granular monitoring while saving cost from installing and maintaining numerous sensors in buildings.

I can see, I can sniff, and I can analyse

We believe that our current approach comprises a key step towards this vision. We dub it the "IEQ Bot," -- an autonomous mobile robot system for measuring indoor environments. This robot can navigate and map a building interior, and measure indoor environmental quality via a wireless sensing platform.

It has a vision system powered by a Kinect camera that can help it localize itself by matching the surrounding patterns with the floorplan. But this system can do much more. The IEQ Bot can avoid people during its patrolling in a socially acceptable manner making it appear as though it has social awareness. It can perform the so called simultaneous localization and automatic mapping (SLAM) to generate a realistic most-up-to-date floor plan for new environments or if building floor plans are not readily available. In the future, it can be employed to detect molds or safety hazards and even assess indoor aesthetics. The IEQ Bot can also identify people in the building through face recognition to enhance security, and even help assess human emotions to help the building better cater to their needs.

The IEQ Bot is equipped with a sensor suite that can cover a range of important IEQ parameters in the buildings such as temperature, humidity, light level, particulate matter (PM) and CO_2 concentration. These sensors can be either communicated to the building system directly, or be allowed to send the data via the robot base upon receiving permission from the building system. These sensors can be deployed at different heights to create a 3D mapping of the space. This is particularly useful for residential applications where parents who are interested to know if their child's crawling on the floor may be exposed to unhealthy levels of PM. We envisage including other sensors to enable a vast number of innovative applications.

Most significantly, the IEQ Bot is equipped with a cyber heart that can analyze real-time data streams. An interpolation algorithm based on advanced learning and optimization was designed to account for the spatial and temporal stamps on each measurement point. This is helpful to create a temporally evolving map of the indoor environment to reveal high-granular informative IEQ trends. In the future, quick identification of pollution sources based on measurements can also be incorporated to demonstrate other real-time decision making capabilities.

New sensing paradigm

Our work proposes a range of interesting topics of research. For example, the sensing paradigm can be formulated into a framework of graph signal processing. With each node representing a location of interest inside the building, a pair of nodes can be connected if the signals sitting on them are deemed to be correlated to one another. Subsequent research questions include the

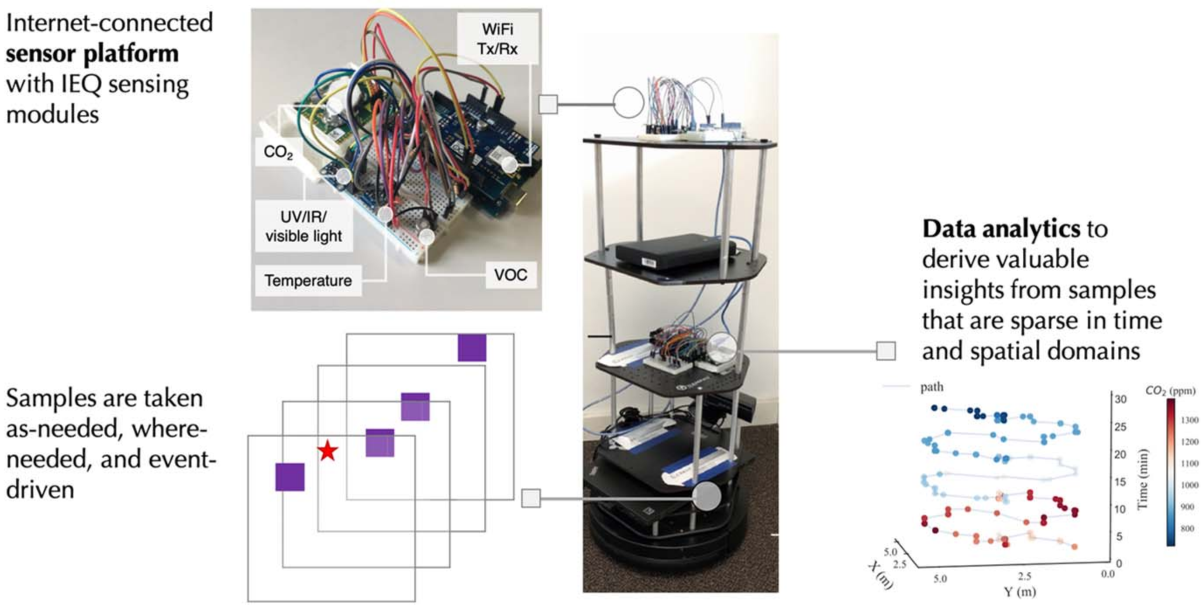


FIGURE 2 The proposed automated mobile sensing platform

minimum number of nodes required for measurement to fully reconstruct the graph signal. This is similar to the problem of critical sampling in traditional signal processing, but applied to irregular graph domain. Other question include, what is the best strategy of patrolling if one wants to identify outlier signal on the graph? Even more fundamentally, what would the underlying graph look like, and how can we identify underlying graph topology? These questions represent the frontier of this emerging field of graph signal processing, and would have a great impact on the efficient operation of new sensing paradigm and understanding of building indoor dynamics.

Automated, mobile, and in action!

In laboratory studies, we demonstrated that the IEQ Bot's analytics system can accurately estimate gas concentrations throughout a building compared to measurements from a set of fixed and densely configured sensors.

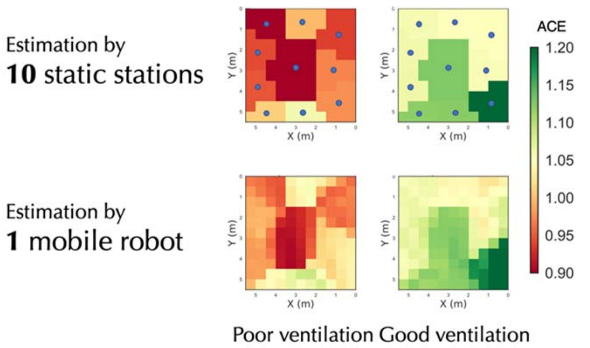


FIGURE 3 Experimental validation of the effectiveness for indoor air quality assessment

Our results indicate that this approach provide good sensing capability with a minimal sensor cost and calibration efforts. We also use the mobile platform to evaluate the well-known metric for ventilation efficiency referred as air change effectiveness (ACE), which requires interpolation of the signal in both the temporal and spatial domain. Our comparison with the ground truth, given by a highly dense sensor network, indicates high-accuracy of the IEQ Bot.

A small video of the IEQ Bot in action in a real building is provided here: (https://www.youtube.com/watch?v=QPwYcRECZWY). The video shows the device, the view from the "robot cam," and a visualization of its mapping software, as it navigates through the case building.

In summary, we have developed a robot called IEQ Bot that could be used to monitor a wide range of building metrics: thermal comfort, lighting, air quality, acoustics, and pollutant source identification. This robot provides the opportunity for a unique method in building commissioning process and post-occupancy evaluation.

Reference:

Jin, M., Liu, S., Schiavon, S., & Spanos, C. (2018). Automated mobile sensing: Towards high-granularity agile indoor environmental quality monitoring. Building and Environment, 127, 268-276. Link: https://www.sciencedirect.com/science/article/pii/S0360132317305012

Best paper award from Building and Environment: https://www.journals.elsevier.com/building-and-environment/news/building-and-environment-2018-best-paper-awards

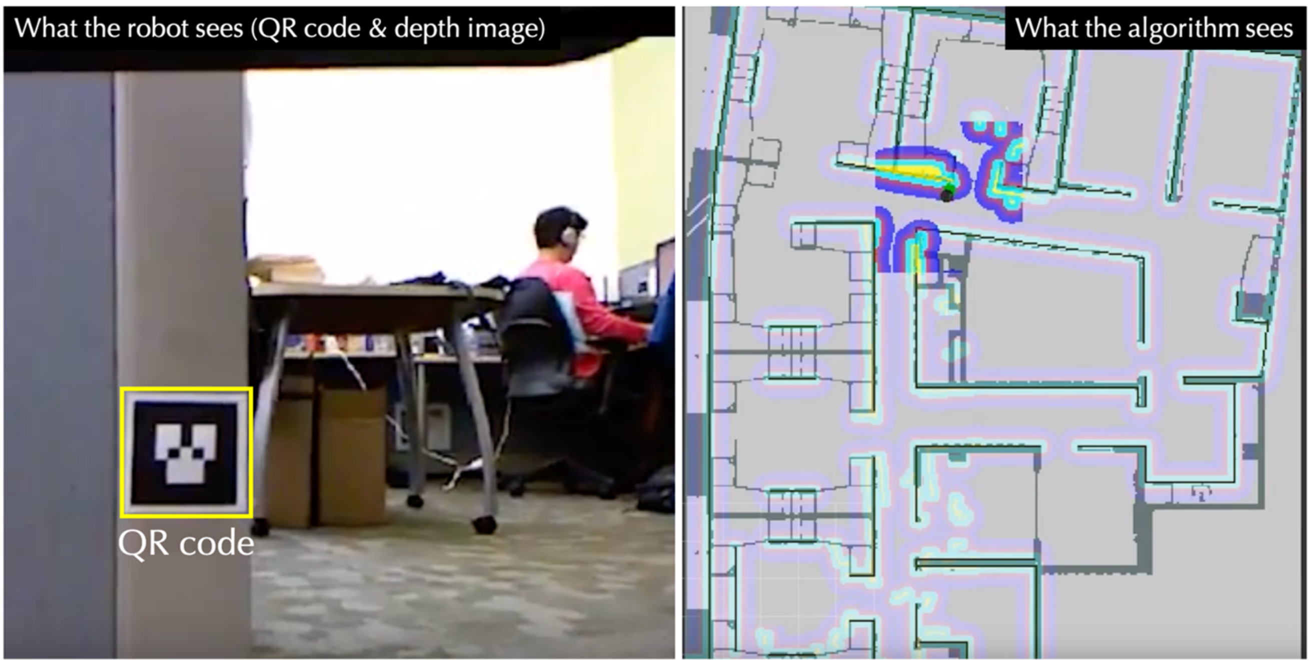


FIGURE 4 Robot in action, showing the camera view (left), and the indoor positioning system (right)

The PMV-PPD model is not as accurate as you think

Toby Cheung and Stefano Schiavon

The predicted mean vote (PMV) – predicted percentage of dissatisfied (PPD) model is the most commonly used thermal comfort model used to predict, respectively, the subjects' thermal sensation and the percentage of dissatisfied responses with the thermal environment. Notwithstanding the well establishment of PMV-PPD model in thermal comfort standards, its prediction accuracy is frequently questioned through assessments in real buildings. Using the world largest thermal comfort field survey database (http://www.comfortdatabase.com), we verified the model accuracy by comparing the predicted (PMV-PPD model) and observed (in real buildings) values.

PMV model

We found that the predicted thermal sensation using PMV model, on average, has one scale unit different form the observed thermal sensation (OTS). This is a lot given that the total range is seven units. We found that the overall accuracy of PMV was only 34%, meaning that subject's thermal sensation in real building is incorrectly predicted two out of three times when using PMV model. It is not a lot better than the prediction accuracy (17%) of a 7-point scale random model. The PMV model had a slightly higher prediction accuracy at sensation close to neutrality, while the accuracy declined towards the hot and cold sensation ends when it would be most needed. The tendency of overestimation indicates an energy saving potential by temperature set-point flexibility at the predicted hot and cold environment.

The PMV model requires six inputs (air temperature, mean radiant temperature, air speed, clothing insulation and metabolic activity). Many of this parameters are practically impossible to measure or estimate in real conditions. To overcome this problem, we developed a simple thermal prediction model just based on air temperature and achieved an accuracy of 35% in thermal sensation prediction, which is comparable to the PMV model. It suggests that the PMV model, requiring six input parameters, may be too complex for thermal sensation prediction in real buildings, whilst a simple model based on readily-available inputs could be more applicable.

PPD model

PPD index is dependent to the PMV value. We found that, under the same PMV predicted thermal condition (PMV_{bin} in x-axis), the PPD model was not able to predict the observed percentage of unacceptability (OPU) from respondents in real building (compared between red and grey line). While under the subject reported thermal condition (OTS_{bin} in x-axis), the accuracy of PPD model to predict OPU was significantly improved (compared between purple and grey line). This suggests that poor prediction performance in PPD model is mainly ascribed by the inaccuracy of PMV model. Given that in practice the real thermal sensation is not known, the PPD model is not useful.

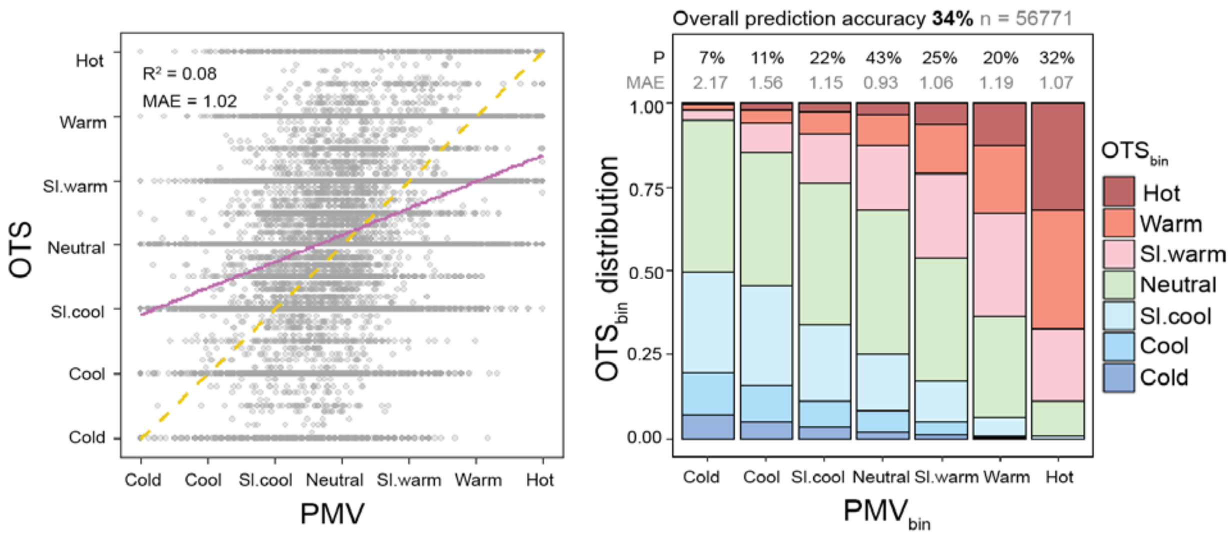


FIGURE 1 Prediction accuracy of PMV model

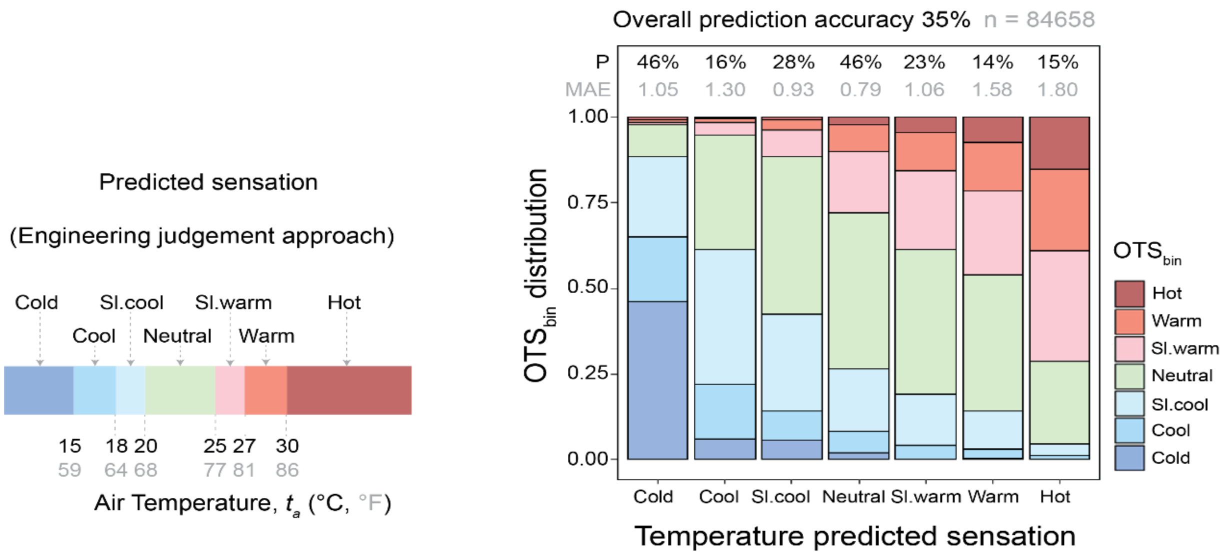


FIGURE 2 Temperature based thermal sensation model: Temperature cut-off criteria (L); Prediction performance (R)

Using the world largest thermal comfort database, we demonstrate the PMV-PPD model has low accuracy in predicting subject's thermal sensation and percentage of unacceptability in real building environment. The inaccuracy is mainly attributed by poor prediction performance of PMV model. We suggest to use a simpler model with less input parameters.

Reference

Cheung T, Schiavon S, Parkinson T, Li P, Brager G. 2019. Analysis of the accurayc on PMV – PPD model using the ASHRAE Global Thermal Comfort Database II. Building and Environment, https://doi.org/10.1016/j.buildenv.2019.01.055

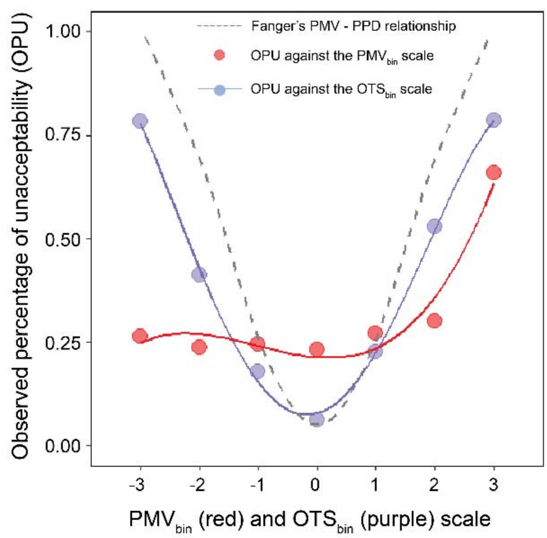


FIGURE 3 Prediction accuracy of PPD model

Materials and manufacturing for energy-efficient tropical air-conditioning systems

Hayden Taylor

This research addressed the function and formation of micro- and nano-structured heat-transfer surfaces, with a view towards raising the energy-efficiency of air conditioning in tropical climates. Much of the anticipated future growth in the use of air conditioning will occur in the tropics, where the high humidity means that as much as 80% of the heat removed from air during conditioning is latent. In these conditions, conventional heat exchanger surfaces flood with condensed water, impeding heat transfer, lowering efficiency, and harboring bacteria and fungi that can make the air unsafe. Alternative system configurations involving advanced desciccants, radiant cooling, and novel water-permeable membranes hold great promise, but relatively simple processes that can enhance the performance of the most common existing system designs could have immediate impact.

Scalable superhydrophobic coating processes for air-side heat exchanger

Conventional cooling coils are either untreated or have a polymeric hydrophilic (water-attracting) coating on them, which enables a water film to form and actually impedes heat transfer. An alternative possibility is to render the surfaces highly hydrophobic (water-repellent), causing dropwise condensation which is associated with higher overall heat transfer coefficients. Dropwise condensation had been widely investigated experimentally, but had seen little industrial adoption because (a) scalable, affordable coating methods had not previously been proven, and (b) no plausible scheme for dealing with the droplets shed from the heat exchanger ('carryover') had been proposed. We invented a coating method that can apply a nanoporous zinc oxide coating to aluminum in a simple two-stage immersion process that uses extremely inexpensive materials. The coating is highly thermally conductive and mechanically robust compared to conventional coatings. Moreover, we developed understanding of how to control the process precisely, to produce a surface that rapidly sheds condensate rather than pinning droplets to the surface.

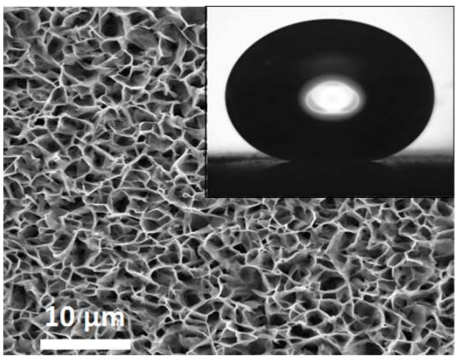


FIGURE 1 Porous zinc oxide film after hydrothermal deposition on to aluminium. Inset: water droplet resting on a silanized zinc oxide film (droplet diameter is approximately 2 mm)

This work was disseminated in two publications in Materials Research Express. One publication developed a statistical model that links the macroscopic wetting performance of a surface to the random distribution of key geometrical characteristics of pores in a film, particularly the re-entrant angle of pore sidewalls. Another publication characterized the microstructural properties of the films and their condensing performance in the context of the statistical model. No one had previously offered a statistical perspective on the relationship between liquid properties such as surface tension, geometry, and wetting performance. Until our work, attempts to model the relationship between surface geometry and surface wetting or liquid-repellent behavior had almost exclusively used deterministic models with fixed geometries. We showed the value of a statistical approach in capturing how a given surface responds to a wide range of different liquids that can wet different fractions of pores.

The ZnO coating process is patent-pending, and has been licensed to Nelumbo, a spin-out from Professor Taylor's group, which was founded by SinBerBEST-funded postdoc Lance Brockway and undergraduate researcher Liam Berryman in 2016. Nelumbo has now been developing the technology successfully for more than two years.

Complementary to the ZnO process has been the creation of a spinodal decomposition-based technique for forming highly water-repellent films composed of microspheres of the polymer PVDF. Such films are well described by an extension of our statistical surface modeling framework, and have the advantage of being less substrate-specific than the ZnO process. They are, however, less thermally conductive, and are likely to find their most promising applications on non-heat-transfer surfaces, for example for capturing and removing condensate droplets shed from a heat exchanger surface into flowing air. There was also a patent application arising from this process invention. The materials developed are now being employed to design a new class of air handler for use in tropical climates.

Reference

Brockway L and Taylor H, "A statistical model for the wettability of surfaces with heterogeneous pore geometries," Mater. Res. Express, 3, 10, p. 105039, 2016.

Brockway L and Taylor H, "A nanoporous, ultrahydrophobic aluminum-coating process with exceptional dropwise condensation and shedding properties," Mater. Res. Express, 4, 4, p. 045003, 2017.

Development of Translucent Concrete Panels

Khalid Mosalam

The translucent concrete panel (TCP) is a type of the complex fenestration system (CFS) that has been developed to reduce artificial lighting demand by capturing and delivering natural light into the interior of a building. The TCP consists of an optical fiber array embedded in concrete to channel diffused sunlight into a building.

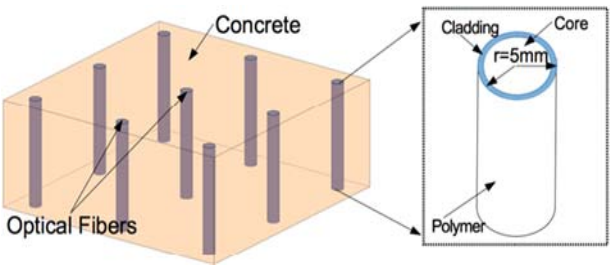


FIGURE 1 TCP model with embedded optical fibers

In this project, the energy efficiency of the TCP has been studied with a combination of both numerical simulation and physical experiments. Factors considered in this research include heat conduction, solar radiation and light switching behavior of the occupants. This research attempted to optimize the energy performance of the TCP by changing design parameters like optical fiber density, arrangement of fibers, the tip finishing of the fibers and use of light concentrators. Currently, a novel power-generating TCP is being tested on the Heliodon testbed.

TCPs as an Energy-Efficient Building Façade

In this research, the energy performance of the TCP has been studied through numerical simulation considering both the coupling between the distribution of illumination from daylight simulation and the light switching behavior of the occupants and that between the solar radiation and the heat conduction of the TCP. The main conclusion of the study is that TCPs are able to cut energy expenditure by 18% for an optimized fiber volumetric ratio of 5.6% by reduced demand for artificial lighting and heating in cold weather while keeping the overheating from solar radiation relatively low in hot weather.

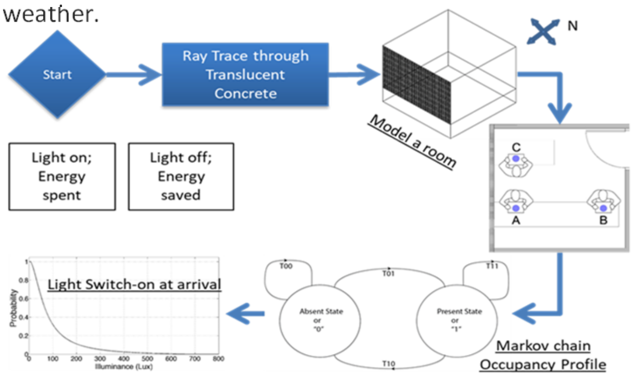


FIGURE 2 Energy Efficiency Simulation of TCP

TCP Experimental Assessment

This study assessed the daylighting performance of TCPs through experiments conducted under real sky conditions with an innovative Small Portable Test Bed, capable of simulating a building envelope and simultaneous testing of all façade faces. Several TCPs with various optical fiber diameters and volumetric ratios have been tested. Then, optical fibers with different tip geometries (i.e., flat, hemispherical and coned tips) have been tested. The effect of the compound parabolic concentrators (CPCs) has also been tested.

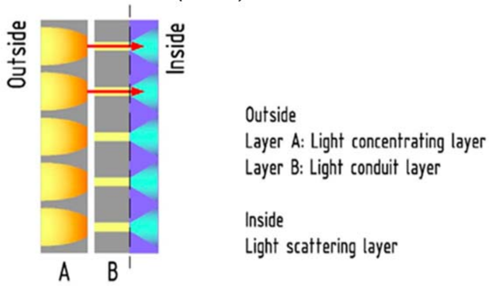


FIGURE 3 The TCP Outfitted with CPCs

The test results have shown that the TCP with CPCs improves the illuminance distribution in the building interior by scattering sunlight. The geometric modification of the optical fibers tips is shown to have improved the daylight distribution.

Hardware-in-the-Loop Daylighting Simulation of TCPs

This research combines the numerical daylighting model in Radiance with the physical model of the TCP with the hardware-in-the-loop simulation framework. A CUBE 2.0 luminance sensor capable of measuring the luminance components in the 145 Klems Basis angles composing a hemisphere has been developed as the interface between the measured physical domain and the simulated cyber domain. This research has demonstrated the potential to apply hardware-in-the-loop simulation in the prototyping and optimization of the CFS.

Ongoing Test of Power-Generating TCPs

Currently, a test is being carried out on a novel power-generating TCP. This power-generating TCP combines photovoltaic (PV) panels with TCP. The front TCP serves as a protection layer and preserves the building aesthetics, while the back PV generates electricity. This test is conducted using the Heliodon to simulate daylight conditions at different locations and day times.

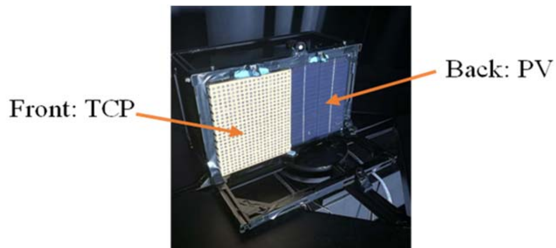


FIGURE 4 Heliodon Test Model of TCP+PV

Detecting and Diagnosing Incipient HVAC Faults

Baihong Jin, Seshadhri Srinivasan, Alberto Sangiovanni-Vincentelli, Kameshwar Poolla

Detecting chiller or air-handling unit (AHU) faults at incipient stage is vital for operating the heating, ventilation and air-conditioning (HVAC) systems efficiently and safely. In particular, detecting faults which are less perceivable and not hindering regular operations called soft-faults are challenging to detect on one hand, but left undetected could reduce the operational efficiency or even lead to significant maintenance costs. It is also important to meet energy standards (e.g., LEED) and other emerging paradigms (e.g., zero energy buildings). Building automation systems with FDD can provide technology leadership to service providers and reduce building energy costs in buildings. The FDD market has seen an exponential growth in recent years and is expected to grow due to recent advances in technology such as the Internet of Things (IoT) and deep-learning. The National Institute of Standards and Technology project on using FDD for commercial HVAC system enhanced the energy efficiency by 10-30% and a demonstrator was designed for knowledge transfer to private sector. The project reported that automated FDD applied at component level and scaled to the whole system by composing them can eliminate false alarm thus helping operators cope up with true alarms effectively.

This is analogous to common labelling programs in the food industry. Recognizing its potential and importance, a growing number of governments around the world started to implement benchmarking (or energy disclosure) policies. Such policies include imposing regulations to meet minimum energy efficiency standards, certificate schemes for self-to-peer group comparisons, among others. As an example, the Building and Construction Authority (BCA) of Singapore publishes its energy benchmarking report every year.

The recent advances in technology enable deploying sensors and computing power ubiquitously. Exploiting this feature significant intelligence can be built to current FDD systems by aggregating more information and making knowledge with such information using deep-learning models. Current FDD systems widely use a business logic based on a sensor measurement to inform whether a maintenance operation is needed on a component or not. For example, a clogged air-filter in Air Handling Unit (AHU) can be detected by employing a differential pressure sensor across the upstream and downstream air and writing a simple business logic that a drop in pressure means a clogged filter. To detect such equipment-level faults early during their life-cycle, deep learning is a promising approach due to its ability to build knowledge directly from labelled sensor data. One challenge that prevents the further adoption of deep learning FDD approaches is that deep neural networks perform less well on examples that are not well represented in the training distribution. In the FDD context, training data that represent incipient faults are typically more difficult to obtain than data representing the normal condition or severe fault conditions. Therefore, a method that can indicate potential incipient faults, especially when labelled data for incipient faults are not available at training time, will be very much desired for FDD applications.

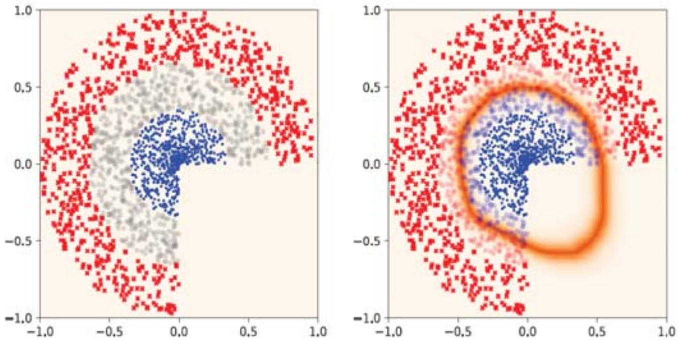
FIGURE 1 Detecting incipient faults in building chillers

In this project, we proposed a Monte-Carlo dropout (MC-dropout) approach to enhance supervised learning pipeline, so that the resulting neural network, when trained with a dataset only comprising normal and severe fault data, will have the ability to detect and diagnose incipient faults that it has not seen before. The main idea of MC-dropout is to randomly drop units along with their connections during both training and test phases, which provides intrinsic randomization into our neural network model. The method leverages the intrinsic predictive uncertainty within MC-dropout networks to indicate incipient faults. This is a very useful technique for predicting incipient faults. We studied the performance of MC-dropout on the ASHRAE RP-1043 dataset using data collected from a 90-ton chiller. Our study illustrated that MC-dropout approach can detect incipient faults in chillers efficiently even without labelled data for those incipient faults.

Reference

Jin, B., Li, D., Srinivasan, S., Ng, S. K., & Poolla, K. (2019). Detecting and Diagnosing Incipient Building Faults Using Uncertainty Information from Deep Neural Networks. Accepted in 2019 IEEE International Conference on Prognostics and Health Management: Available for download at: https://arxiv.org/pdf/1902.06366

Jin, Baihong, et al. "A One-Class Support Vector Machine Calibration Method for Time Series Change Point Detection."; Accepted in 2019 IEEE International Conference on Prognostics and Health Management: Available for download at: https://arxiv.org/pdf/1902.06366



(a) Distribution of data points

(b) Decision boundary

FIGURE 2 A toy example in 2 dimensions. (a) The healthy state data (in blue) are confined in a circle with radius r = 0.3 centered at the origin. The severe fault data (in red) reside outside r = 0.7. In between the blue and the red points are the intermediate states (gray) that are not observed in the training distribution. (b) The decision boundary (orange) given by a trained non-dropout neural network classifier. Intermediate-level fault data points classified as healthy are shown in light blue, and those classified as faulty by the decision boundary are shown in light red.

The SinBerBEST Air-conditioning and Mechanical Ventilation Testbed

Giridharan Karunagaran

The SinBerBEST ACMV testbed consists of two air handling units (AHUs) supplying a total of four testbed rooms. The testbed is located within the BEARS dry lab space in the 11th floor of CREATE tower.

Mechanical Systems:

CREATE indoor air is heated and humidified to match outdoor air temperature and humidity (outdoor air is thus emulated) and is then supplied to the AHUs for cooling and dehumidification. Four Variable Air Volume (VAV) boxes vary the supply airflow rate to achieve the desired temperature in each of four testbed rooms (VAV principle).

Ventilation is also regulated in each set of two rooms by recirculating the air from the testbed rooms and mixing a portion of it with the emulated outdoor air.

In addition, on the supply air path leading to the four testbed rooms, heaters and steam injectors are installed to enable the temperature and humidity control of the supply air. Hence, high temperature and high humidity can also be attained in the testbed rooms.

Instrumentation and Control:

The SinBerBEST ACMV system is heavily instrumented with high quality sensors that measure all relevant parameters such as air temperature, pressure, CO_2 concentration, flow rate etc. All of the sensors, the actuators that modulate the valves and dampers, the VFDs (Variable Frequency Drives) that drive the fans, the duct heaters and the duct humidifiers are all centrally connected to a National Instruments' Real-Time Controller.

The control loops are thus programmed using National Instruments LabVIEW and executed on the real time platform. The LabVIEW front panel or UI provides the operator full command of the ACMV system (Auto/Manual Modes, Logging, Visualization, Warnings and Alarms).

The testbed rooms are also heavily instrumented and National Instruments data acquisition platforms are used to gather signal data and log them for analysis.

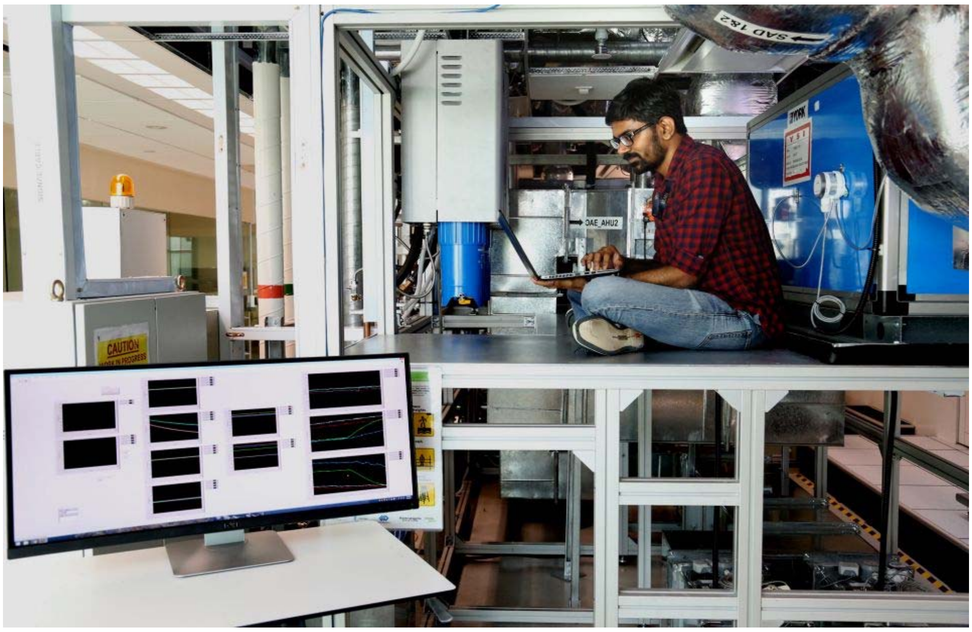
Research:

The main objective of the SinBerBEST ACMV testbed is to function as a research platform on three fronts:

1. ACMV Control Algorithm Research: Using modern control strategies such as model predictive control for energy reduction, the overall ACMV control can be implemented and studied under strict controlled conditions.
2. Indoor Air Quality and Thermal Comfort Research: Physical and human subject studies can be conducted with desired conditions in the space.
3. ACMV Mechanical Subsystems Research: Different ACMV subsystems on the SinBerBEST testbed can be interchanged with test units in order to compare and evaluate their performance. For example, AHUs with special hydrophobic coatings on the coils can be install on the ACMV testbed and evaluated in relation to a normal AHU.

FIGURE 1

SinBerBEST Air-conditioning and Mechanical Ventilation Testbed



Annual SinBerBEST Symposium 2019.

The SinBerBEST Annual Symposium will take place on the 2nd floor of the CREATE Tower in Singapore on Monday, August 5, 2019. The main theme of this Symposium is: People, buildings and data – shaping a sustainable future.

At this meeting, we will present keynotes from agencies and leading researchers related to SBB research and provide justification for NRF investment to Singapore stakeholders. There will be three external keynote speakers from University of Toronto, École polytechnique fédérale de Lausanne and University of Pennsylvania. We will also hear from the SinBerBEST Principal Investigators and Post-Doctoral Scholars on highlight innovation, research accomplishments, education, training and testbed capability that SBB is engaged with other Singapore entities. Programs will run from 8:30AM to 6:00PM approximately.

To register for the symposium, please click on the link below to fill up the formv:
https://forms.gle/N9MDT56FYW5gV8mT9

IEEE International Conference on Sustainable Energy Technologies and Systems (ICSETS) 2019

IEEE International Conference on Sustainable Energy Technologies and Systems (ICSETS) is a new international conference which is planned to bring together professionals and executives in the energy sector, electrical power companies, manufacturing industries, research institutes and educational bodies to share and exchange ideas and information pertaining to sustainable energy technologies. The 1st ICSETS will be organized in Kalinga Institute of Industrial Technology, India early 2019. SinBerBEST NUS Lead-PI A/Prof. Sanjib Kumar Panda, postdoctoral researcher Dr. Hoang Duc Chinh, and Dr. Jayantika Soni are members of the conference committee.

Url: http://icset-ieee.org/2019/index.html

The release of ICSETS 2019 conference proceeding during opening ceremony.

New Staff Member

Pandarasamy Arjunan joined the SinBerBEST program as a postdoctoral scholar where he will work under the guidance of Prof. Kameshwar Poola (UC Berkeley) and Dr. Clayton Miller (NUS) for “Theme D: Data Analytics for the Built Environment”. He completed his PhD in computer science from IIIT-Delhi with his research focus on the design, development, and implementation of extensible middleware systems for implementation of building energy management applications ranging from occupancy

sensing to identifying abnormal energy usage in buildings. He has also worked on scalable energy monitoring and anomaly detection methods for a large number of buildings at utility scale using smart meter data.

His current research is focussed on developing robust and explainable building energy benchmarking system at the city-scale. Energy benchmarking is one of the widely used practices for measuring energy performance of a building and comparing it with similar buildings. By leveraging advanced machine learning and Explainable Artificial Intelligence (XAI) methods, he designs a fair, robust and understandable energy benchmarking system for Singapore. He also investigate how smart meter data collected at fine-grained resolution can be used, instead of using only the static building attributes, for benchmarking.

POWER@NUS team from ECE Dept awarded Best Overall Student Team in the IEEE Empower a Billion Lives competition (EBL)

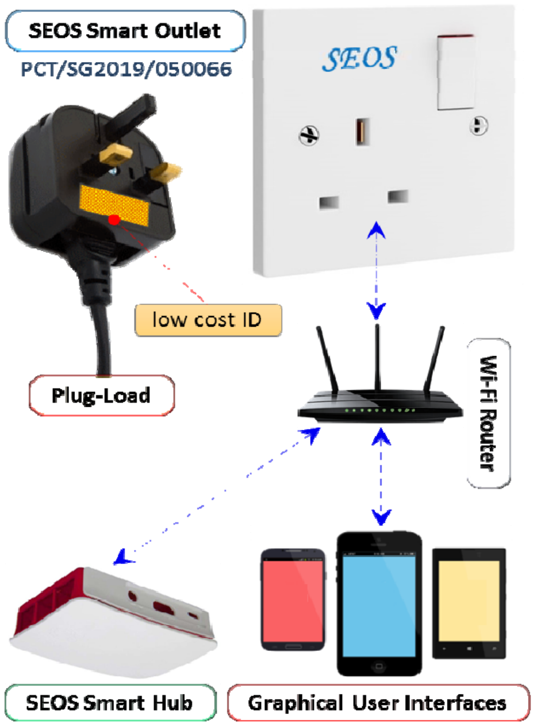
The team POWER@NUS, comprising of PhD students (Jaydeep Saha, Rohit Chandra, Sandeep Kolluri, Binita Sen, Palak Jain and Kamala Srinivasa Rao) and researchers (Rajesh Sapkota, Prathamesh, Md Waseem and Santosh Janaki Raman) from Electrical Machines and Drives Lab, ECE department, mentored by Associate Professor S K Panda and Dr. Eddy Blokken (SERIS), participated in the Empower a Billion Lives competition organised by IEEE. The team submitted their proposal and were selected for the South-Asia regional round at PEDES 2018, IIT Chennai. They have been awarded as the Best Overall Student Team, South-Asia region on 20th December, 2018 for the 2018-19 edition of the competition and have qualified to participate in the Global Final round to be held at ECCE, Baltimore, USA in September, 2019. The team has proposed a community empowerment solution via rural electrification along with a business model, where renewable energy is harnessed as the main source of energy with adequate respect given to risks.

Relevant webpages:
http://empowerabillionlives.org/
http://ece.nus.edu.sg/drupal/?q=node/126

Award ceremony for IEEE EBL competition

Smart Electrical Outlet / Socket (SEOS)

Smart Electrical Outlet/Socket (SEOS) US Provisional Patent Application No. 62/626,175 underwent Patent Cooperation Treaty (PCT) filing on 04.Feb.2019 as PCT/SG2019/050066. The patent application describes a plug-load management solution consisting of smart electrical outlet/socket devices and related systems/services proposed and implemented by SinBerBEST researchers. The inventors are Dr. Krishnanand K. R., Dr. Hoang Duc Chinh, Manish Gupta, A/Prof. Sanjib Kumar Panda and Prof. Costas Spanos.



Communication architecture of the plug-load management solution within a building

Interview with Dr. Aleksandra Lipczyńska

For this issue, we talked with post-doctoral scholar Aleksandra Lipczyńska who left SinBerBEST's research team to begin her academic career as an assistant professor at the University of Technology. Dr Aleksandra Lipczyńska is a leading expert on indoor air movement and thermal comfort. She obtained her Ph.D. at the Silesian University of Technology in Poland in collaboration with the Technical University of Denmark. She joined SinBerBEST in January 2016. In this interview, we learn about Aleksandra's experiences with SinBerBEST.

Tell us about your area of expertise.
My expertise and research interests lie in the area of indoor environmental quality, air distribution and air-conditioning systems. More specifically, I examine how people respond to different conditions of the built environment, with the main focus on thermal comfort and indoor air quality. I also study how HVAC systems affect building energy consumption. In the SinBerBEST program, I worked within theme A with most of my research work focused on increased air movement and elevated room temperature and how it can improve occupants' comfort while at the same time decreasing building energy usage.

Why is this research field so important?
Many people are aware that HVAC systems are one of the main contributors to building energy consumption, especially here in the Tropics. Unfortunately, they are oblivious to how different conditions inside buildings can affect their own comfort, health and productivity. Focusing soley on energy performance may lead to poor indoor environmental quality, which may have a negative impact on the occupants. Considering that 95% of our time is spent in the indoor environments, we should strive to improve comfort, satisfaction and health. Currently, the average occupants' satisfaction on their office environment is around 60% - below the 80% required by today's building standards. We look for ways to create optimum conditions in buildings so that there will be higher occupants' satisfaction and enhanced productivity.

What made you join SinBerBEST?
Firstly, it was an opportunity to work with world renowned researchers, Prof Stefano Schiavon and Prof William Nazaroff. Secondly, I decided because of "curiosity of the world". Before SinBerBEST, I have lived most of my life in Poland followed by nearly 2 years in Denmark. After my stay in Denmark, I wanted to experience more and I knew that moving to Singapore will be a valuable career and an amazing life experience for me. This allows me to get familiarized with local cultures, conditions and a way of working that is different from what I am accustomed to.

What were your goals in SinBerBEST and did you achieve all of them?

After obtaining my PhD. I was looking for a place where I could mature as an independent researcher. Prof Schiavon created perfect conditions for that. With the support and constructive critique, he gives postdocs ample space to find their own research direction, study topics that they found interesting and important and gather valuable experience such as how to manage contacts between academia and industry. I certainly received precious lessons that I will use in my future career.

After 3 years in SinBerBEST, what can you tell about your impressions working in SinBerBEST and living in Singapore?

It was a life changing experience. Singapore is a very vibrant and busy place. Although Europe is bustling, Singapore is on a completely different level. Initially, I had difficulties adapting to the crowd and the high-rise built environment. But I managed to achieve balance in my life with time. I made great friends in Singapore and I'm leaving with a lot of fond memories.

I am very grateful for the time I have spent in SinBerBEST. All the PIs that I interacted offered guidance and support. The research team created a camaraderie among ourselves -- our weekly meetings were always bustling with interesting discussion. Sincere thanks to other members of our BEARS family for the kindness and eagerness to help.

What do you hope to do next?

I love to teach. Even before I moved to Singapore, I knew that at one point I would be looking for a faculty position in a university. After years of acquiring personal knowledge and skills, it is time for me to "give back" what I have received. I hope to emulate my previous supervisors and inspire someone else. At the same time, I will continue with my research work and hope to deliver results meaningful to the field. Lastly, I hope to keep the collaboration with SinBerBEST.

We wish Dr Aleksandra Lipczyńska all the best.

SinBerBEST aims to deliver energy efficient building technologies for the tropical built environment, while optimising human comfort, safety, security, and productivity within the building. This interdisciplinary research project is organised into five themes (A – E) :

A - Human-Building Nexus

B - Smart Technologies and Resilient Buildings

C -Agile Design for Energy Efficiency and Human Comfort

D - Data Analytics

E - Test Beds and Deployments

If you are interested to learn more about our program, participate in our research or use our test-bed facilities, please contact Dr. Zuraimi Sultan at zuraimi.sultan@bears-berkeley.sg

or

visit us at www.sinberbest.berkeley.edu

SinBerBEST

The SinBerBEST program, funded by the National Research Foundation (NRF) of Singapore, is a research program within the Berkeley Education Alliance for Research in Singapore (BEARS). SinBerBEST is an interdisciplinary group of researchers from University of California, Berkeley (UCB), Nanyang Technological University (NTU) and National University of Singapore (NUS) who come together to make an impact with broadly applicable research leading to the innovation of energy efficient and sustainable technologies for buildings located in the tropics, as well as for economic development. SinBerBEST's mission is to advance technologies for designing, modeling and operating buildings for maximum efficiency and sustainability in tropical climates. This newsletter, published quarterly, is to showcase the excellence of SinBerBEST faculty, post doctoral fellows and students.

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