IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Accelerating smart building solutions with enhanced data analytics and optimization	
Project Number	**IMURA1094**	
Monash Main Supervisor (Name, Email Id, Phone)	Jenny Zhou, jenny.zhou@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	A/Professor Ha Bui, ha.bui@monash.edu	*Full name, email*
Monash Department:	Civil Engineering	
Monash ADGR (Name,Email)	A/Professor Timothy Scott; Eng-ADGR@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Anupama Kowli, anu.kowli@iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)		*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. Kishore Chatterjee, head@ee.iitb.ac.in	*Full name, email*
IITB Department:	Electrical Engineering	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
*(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	***CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control***
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1	***Artificial Intelligence and Advanced Computational Modelling***
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	***Sustainable Societies***
7	*Infrastructure*

The research problem

Define the problem

Buildings are among the most critical cyber-physical energy systems, accounting for 30% of global final energy consumption and 27% of total energy sector emissions. With advanced intelligent technology, people now expect buildings to achieve higher energy efficiency and offer occupants more comfortable and healthy environments.

Real-time monitoring using IoT sensors installed at a limited number of locations is the usual approach to facilitate monitoring of building performance in terms of the indoor environmental quality (IEQ), occupant comfort and context-aware services it provides and the energy it consumes in doing so. To unlock the full potential of the data and to enhance the robustness in building management and prediction, this research aims to address the following three problems we observed in real-world deployments and industry practice:

- Spatially- and temporally-sparse monitoring data from sensors cannot represent the dynamic behavior of indoor occupancy and environmental quality: This problem is particularly important since recent research shows the spatio-temporal variations in temperature, humidity and other environmental attributes can affect occupant comfort.
- Poorly placed sensors, sensor faults and degradation lead to a biased control and prediction of the buildings: While the perils of modelling with faulty sensor data are well understood, recent work has also highlighted how models initiated with data from spatially diverse sensors can lead to very different operating strategies.
- Single-attribute optimization limits the progression towards energy-efficient comfort and wellness: Although ventilation and air circulation systems in buildings consume significant energy, occupants continue to express discontent with their building environment, prompting more research in the domain of co-optimization of energy, comfort and air quality.

In this project, we will leverage existing test beds and smart buildings at IITB and Monash campuses to develop models and algorithms that (i) generate dynamically changing, spatio-temporal data capturing occupancy and environmental conditions using *minimal* sensors, (ii) assess and correct sensor data for faults, and (iii) optimize multiple attributes such as energy, comfort and IEQ using data-driven techniques. Our blue-sky research will advance the knowledge in intelligent, sustainable buildings. Our impact and legacy will be assured via a multidisciplinary collaboration (IITB Department of Electrical Engineering & Monash Department of Civil Engineering), smart buildings with high-density sensing networks in both universities, and innovative analytics and modeling approaches.

Project aims

Define the aims of the project

Aligned with the problems described above, this research aims to

- Devise spatio-temporal interpolation algorithms to enrich the sparse sensor data and generate a comprehensive dataset representative of local occupancy and indoor environmental quality conditions.
- Create analytics that use heterogeneous data for anomaly detection of sensors and building components; analytics for correcting faulty sensor data will also be investigated.
- Develop multi-attribute optimization algorithms to manage the trade-offs between occupants' comfort and energy expenditures.
- Design, deploy and test the algorithms in real-world environments available at IITB and Monash campuses.
- Generate, curate and maintain data sets and analytics for smart building research.

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

Year 1 and Year 2 at IITB:

- Acquire the data from the cast study building on the IITB campus
- Develop the initial algorithms, analytics, and optimization models (based on the three objectives mentioned earlier)
- Perform testing and validation with the ground-truth data
- Publish preliminary results in conferences/workshops/journals as appropriate

Year 3 at Monash:

- Acquire the data from the case study building on the Monash Clayton campus

- Further improve the algorithms, analytics, and optimization models with the new data
- Explore industry collaborations for field testing and technology transfer

Year 4 at IITB:

- Evaluate the similarities and differences between the IITB and Monash case studies
- Report results of the studies in top tier journals such as Energy and Buildings, Building and Environment, etc
- Consolidate the 4-year research and prepare the final thesis

Expected outcomes

Highlight the expected outcomes of the project

- Spatio-temporal interpolation algorithms to enrich sparse data in occupancy and indoor environmental quality: these algorithms will provide a rich data set with minimal sensor deployment, thus reducing the electronic footprint required for smart buildings.
- Analytics of heterogeneous data for anomaly detection of sensor and building components: These will help generate reliable sensor data that can be used in closed loop for control of critical building elements such as ventilation and air conditioning.
- Optimization tools for managing the trade-off between occupants' needs and energy penalty: Such tools are needed to explore the Pareto frontier between occupant comfort and energy consumption.
- Field experiments and trials with significant data acquisition and testing.
- Datasets on occupancy, thermal conditions, IEQ, and energy consumption in select environments: Data sparsity is a key barrier for researchers and we will strive to create suitable datasets to promote smart building research.
- Reports and publications in premier conferences and journals: We expect at least 3 journal papers in top-tier publications such as Building and Environment/Energy and Buildings/etc, with one paper specifically dedicated to sensor data which is hard for several researchers to find.
- Possibility of technology transfer and patent generation

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

The availability of low cost sensors, emergence of IoT and the advances in computing make it attractive to explore data-driven techniques for building energy management. Hence, the project outcomes described here will be developed by leveraging the state-of-art algorithms from **machine learning and artificial intelligence**. It is envisaged that these tools will promote occupant-centric building operations and improve energy efficiency of the building stock. This in turn will facilitate sustainable building consumption, a key pillar for **sustainable societies**. In this way, the project is aligned with the identified themes.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

IITB: Assistant Prof. Chirag Deb, CUSE
Associate Prof. Jayakrishnan Nair, EE

Monash: Associate Prof Victor Chang from the Department of Civil Engineering

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

- A skilled and motivated student with background in Electrical Engineering/Computer Science
- A Masters degree is desired, but exceptions may be made of outstanding undergraduate students
- The applicant must have strong analytical and mathematical background, with exposure to computer programming/simulation
- The following skill sets will be of add value but are not mandatory: significant experience with Python/TRNSYS/EnergyPlus, prior project work with sensors/microcontrollers, experience with machine learning/AI applications.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

A subset of the following courses will be mandated*
EE 617 – Sensors in Instrumentation
US 604 – Introduction to Building: Functional Design and Science
US 608 – Green Building Design
EE 731 – Design of Experiment /Taguchi Method for Experimental Research
EE 782 – Advanced Machine Learning
*The three courses required will depend on student background and strengths

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

- IITB has several ongoing projects on smart buildings (via Indo-UK, TiH-IoT and industry funding). There is also a recently initiated Indo-EU project on sustainable local energy communities. The outcomes of this project will complement the research in these identified projects as well as benefit from their outcomes. The PIs will strive to extend collaboration here as applicable.
- On Monash's side, the project will further the collaboration with Building 4.0 CRC, CSIRO, and Smart Manufacturing Hub.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Systems Analysis and control;
Computer simulation;
Sensor and sensor network;
Data science, optimization, algorithms