A Coupled Deep Learning-based Internal Heat Gains Detection and Prediction Method for Energy-efficient Office Building Operation

Shuangyu Wei[1], Paige Tien[1], John Calautit[1], Hua Zhong[2]

1. University of Nottingham; 2. Nottingham Trent University

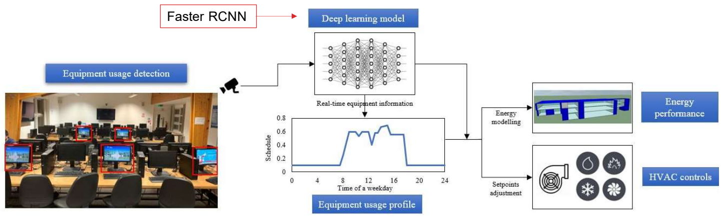
University of Nottingham UK | CHINA | MALAYSIA

NTU Nottingham Trent University

DG23

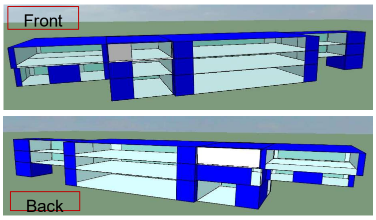
Background

As the major energy consumers in buildings, heating, ventilation and air-conditioning (HVAC) systems consume about 40% of the total energy use. To enable demand-driven HVAC controls to provide a balance between energy reduction and comfort, a vision-based equipment detection approach was developed to accurately detect and predict internal heat emission from equipment in real-time in office buildings using the Faster RCNN model with InceptionV2.



Energy simulation

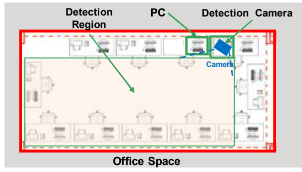
Building energy simulation was run to assess the impact of proposed approach on heating and cooling demand

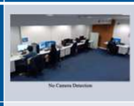


Model of the case study building

Case Study and Scenarios

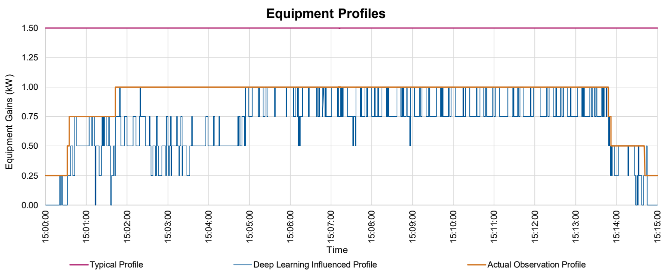
Sustainable Research Building (University of Nottingham)

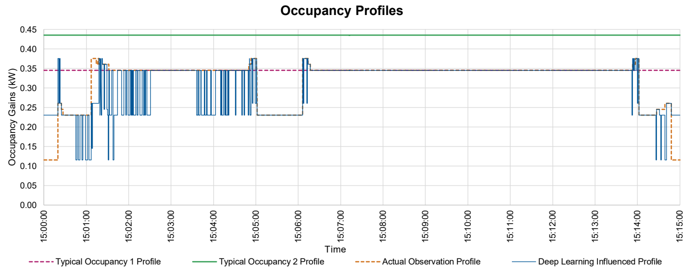


	Scenario 1: Constant Typical	Scenario 2: Equipment Detection Only	Scenario 3: Occupancy Detection Only	Scenario 4: Coupled
Image Representation				
PC Monitor on Profile	Static Profile	Equipment DLIP	Static Profile	Equipment DLIP
Number of PC Monitor On (Equipment)	8 during each weekday and 4 during the weekend	Varies according to the equipment usage	8 during each weekday and 4 during the weekend	Varies according to the equipment usage
	For each PC, it represents 2 PC monitor-on and 1 computer-on Maximum conditions: 4 PCs = (8 PC Monitors turned on, 4 Computers)			
Occupancy Profile	Static Profile	Static Profile	Occupancy DLIP	Occupancy DLIP
Number of occupants' present in room	8 during each weekday and 4 during the weekend	8 during each weekday and 4 during the weekend	Varies according to the actual occupancy	Varies according to the actual occupancy
Occupancy Internal Gains	Max sensible gain: 75W/person		Max latent gain: 70W/person	
Heating & Cooling Profiles	22°C during building operational hours			

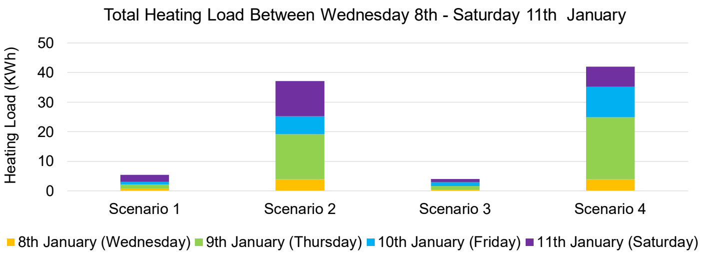
Results

1 **Occupancy and Equipment Usage Profiles**: Overall equipment detection and occupancy activity detection accuracy of 78.39% and 93.60% were achieved. It resulted in up to 54.38% lower heat gains from PC monitors and up to 29.09% lower in occupancy heat gains.

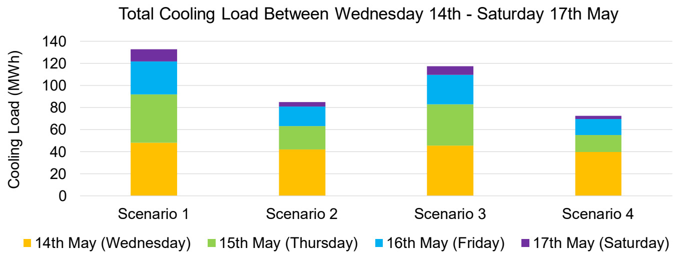




2 **Building Energy Simulation Results**: During **heating season**, although the heating demands were higher when using deep learning profiles, the proposed approach can maintain the comfort level that occupants require.



3 **Building Energy Simulation Results**: During **cooling season**, Scenario 4 estimated the lowest cooling load among all the scenarios and to be 45.37% lower than Scenario 1.



Conclusions

- An **initial demand-driven deep learning-based framework** for detection and recognition of occupancy activities and equipment usage within a building space was developed.
- The proposed model has the ability to identify the occupancy and equipment usage with a relatively high accuracy **(93.60% for occupancy and 78.39% for equipment usage)**.
- **Initial finding** presented that up to **45.37% reduction in energy use for space cooling** could be achieved.
- The ability of the **deep learning detection to inform HVAC systems** will significantly help towards **reducing building energy loads, monitor indoor ventilation and air quality and increase indoor thermal comfort**.