ME Project 2019

Australia's Global University | Faculty of Engineering | School of Electrical Engineering and Telecommunications

Data Analysis for Smart Buildings

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Introduction

Smart Campus Group aims to gain insights into the behaviour of real estate usage on UNSW campus through the instrumentation of IoT devices coupled with data analytics. (Ethics approval number **HC17140**)

This project focuses on building a sensor network system to collect and cleanse sensor data from the HPD camera and beam counters installed in the Electrical Engineering building. Data visualisation based above are presented to answer the question of the elevator and shared study space usage.

Objectives

- Deploy a sensor network based on prior work from our research group.
- Improve the estimated occupancy accuracy by sensor fusion.
- Determine when it is best to schedule elevator repairs/outages.
- Determining break down of elevators (Elevator which breaks down more frequently may need more maintenance).

Results: Visualisation of Elevator Usage

Cleansing Process

- **Dataset**: beam counter data frame collected from week 1-8 in term 3.
- **Fault detection**: find the outage dates and patterns. (**Fig.2 & 3**)
- **Data observatory**: set thresholds to exclude outliers based on fault detection. (**Fig.4**)
- **Noise filtering**: filter the noises – produced when the elevator is stationary. (**Fig.5**)

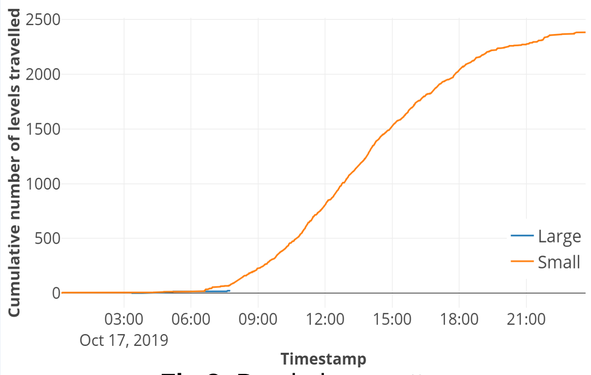


Fig.2: Break down pattern

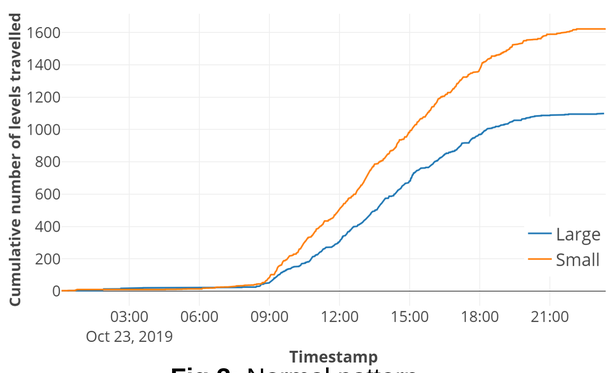


Fig.3: Normal pattern

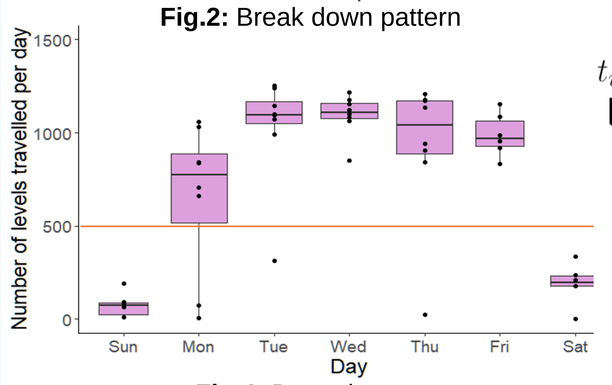
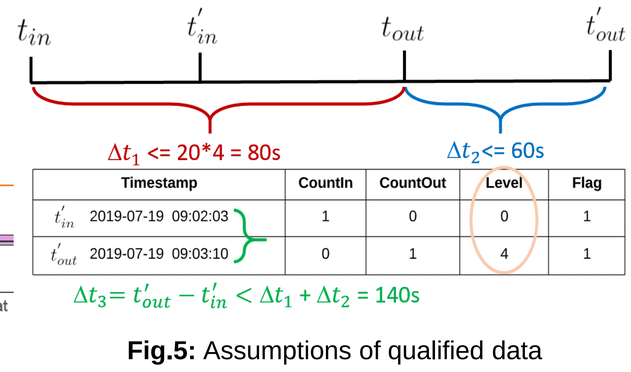


Fig.4: Data observatory



Timestamp	CountIn	CountOut	Level	Flag
t'_{in} 2019-07-19 09:02:03	1	0	0	1
t'_{out} 2019-07-19 09:03:10	0	1	4	1

Fig.5: Assumptions of qualified data

- Large lift broke down for 10 days in 8 observation weeks (17.8%) while no outages for the small one
- Around 4% of whole data records are recognized as noise and filtered out.

Elevator Usage

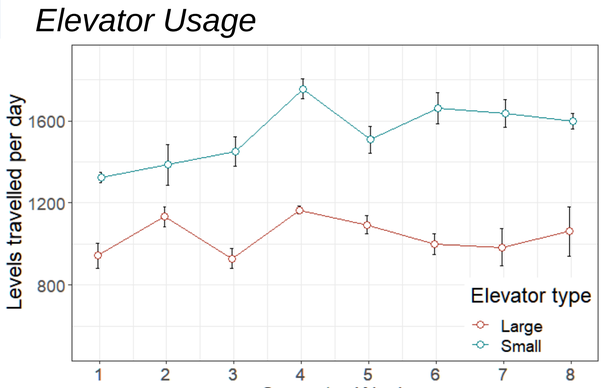


Fig.6: Trends throughout weeks

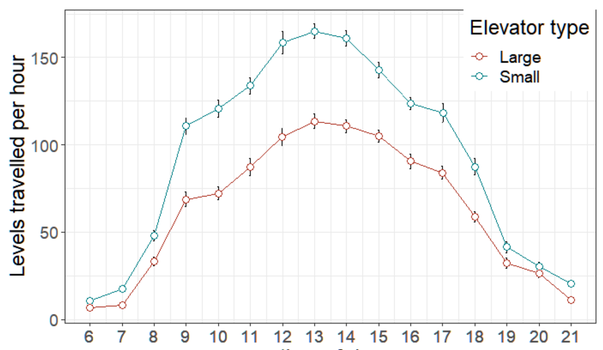


Fig.7: Trends throughout a day

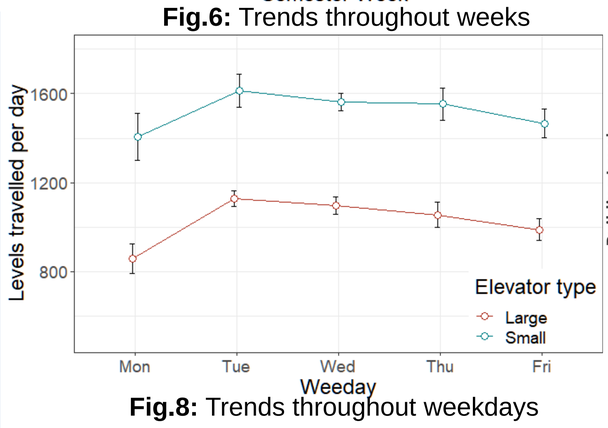


Fig.8: Trends throughout weekdays

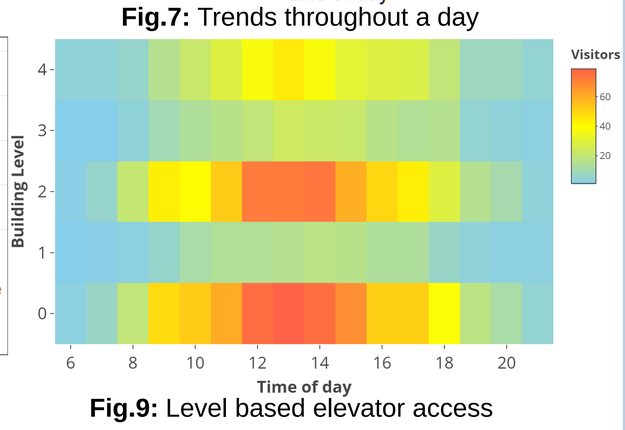


Fig.9: Level based elevator access

- Week 4 occupies the largest usage, ~30% more levels daily than Week1. (**Fig.6**)
- Peak hours are from 12 am to 2 pm on weekdays. (**Fig.7**)
- Small elevator is more frequently used - travel ~50% more levels daily than the large one. (**Fig.8**)
- Ground level and level 2 has the most daily visitors, ~ 3.9 times on level 1&3. (**Fig.9**)

Sensor Network System

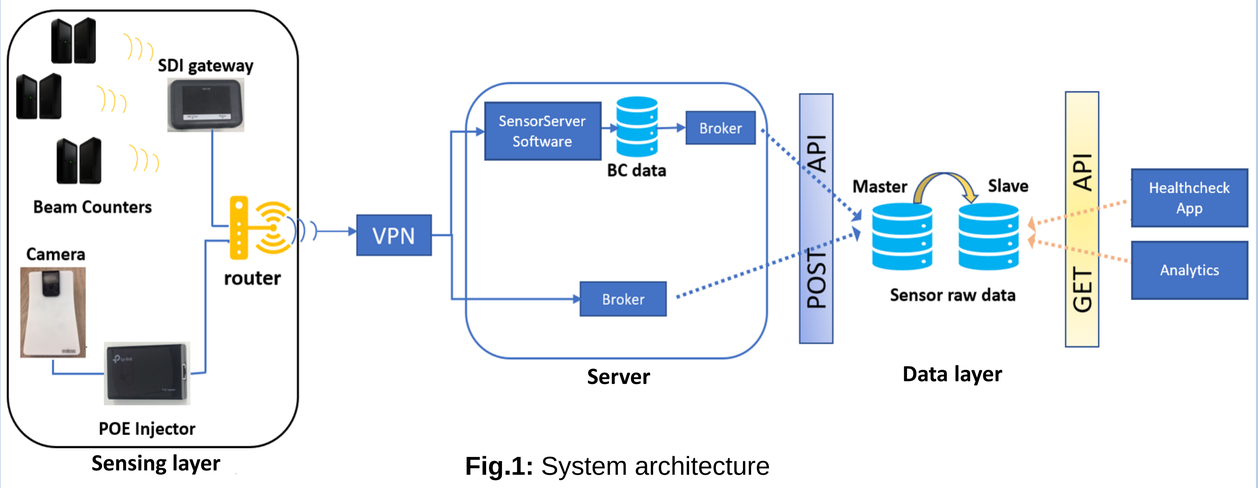


Fig.1: System architecture

*System Design & Implementation (**Fig.1**)*

- **Sensing layer**: contains various sensing, communication and power adapter device.
- **Server**: run the broker scripts which uniform sensing data into a common format.
- **Data layer**: a load balanced centralized database from the sensing layer via POST API.
- **Healthcheck**: web application to indicate the operational conditions of sensors.

Results: Visualisation of Shared Study Space Occupancy

*Camera Performance Analysis (**Fig.10**)*

Observed errors are separated into 2 main types:

- Recognition of an object as person. (false positive
- Failure to detect a person. (false negatives)

3 methods to tackle the above problems:

- Adjust the detection threshold, i.e., the minimum confident percentage.
- Add the non-detection zones to minimize false positives.
- Turn on hi-res image mode.

Fig.10: Accuracy of a camera

*Sensor data Fusion (**Fig.11**)*

- **Data collection**: invoke GET API for the beam counter and camera data.
- **Data preparation**: prepare a data file – setting up the structure & append useful information. } **Fig.13**
- **Data cleansing**: window average filtering camera data & fused with beam counter data.
- **Data explanation**: plot graphs to show the fused result and ground truth. (**Fig. 14**)

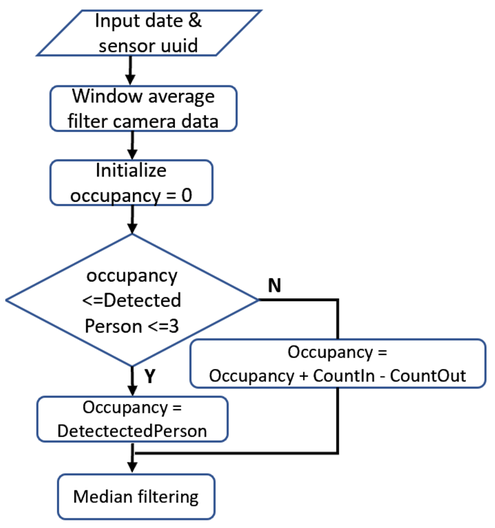


Fig.11: Data fusion flow chart

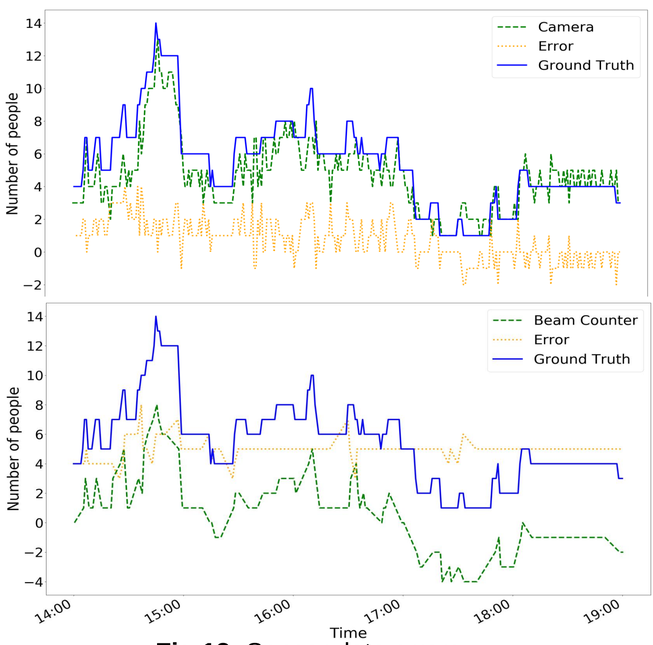


Fig.12: Sensor data errors

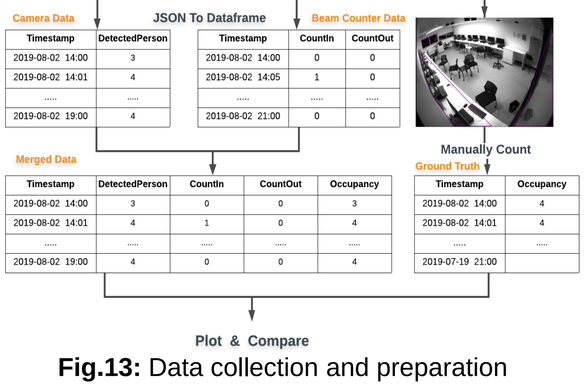


Fig.13: Data collection and preparation

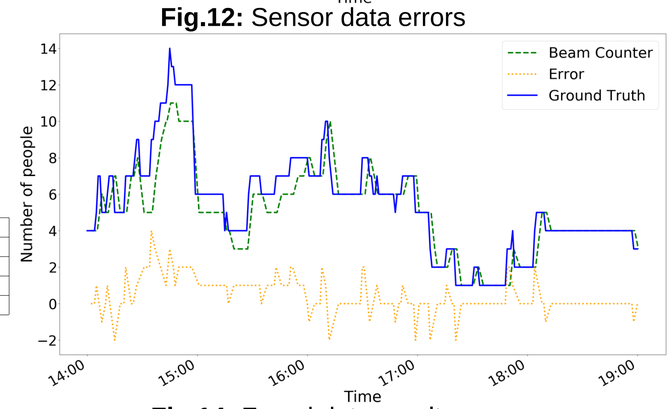


Fig.14: Fused data result

- Beam counter and camera data suffered from noise and cumulative errors separately. (**Fig.12**)
- Window length is chosen as 5 minutes via trial.
- Observed from experiments, the filtered camera data is trustworthy when "DetectedPerson" <= 3 (accuracy ~95%), selected as a standard to reset the occupancy – clear beam counter errors.
- Compared with sole camera data, data fusion reduced MSE from 2.093 to 0.923.

Conclusion

- A sensor network system has been deployed and stabilized.
- Sensor fusion has been proved to improve the accuracy.
- A appropriate timepoint for repairs could be 6-8 am Mondays on level 1.
- The large elevator may require more scheduled maintenance because of its much higher error rate even though it is not used as frequently as the small one.

Future Work

- Use stronger double sided tape for the cameras to prevent them from falling down.
- More robust algorithm of data cleaning for noises from the beam counter and camera.
- Improve the stability of the sensor network system.
- Inspect more complicated scenes such as the whole level based data analysis.