



# Extraction of Air Conditioner Unit Indicators from Proximal Infrared Remote Sensing of Buildings

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## Introduction

## Data & Methodology

## Findings & Conclusions

In this work, we use the “Urban Observatory” (UO) methodology for studying dynamics in complex urban systems through time-dependent proximal remote imaging to characterize energy consumption related to user behavior in a Singapore residential building via infrared (IR) imaging. We present machine learning (ML) techniques for image processing and extraction of air conditioner time series that encode end use behavior.

- Data**
- IR image data sampling 1 image/min from 1/24 7pm to 1/25 4am, 2020
  - 538 frames
  - 190 hand labeled pixels by type: AC unit (30), building facade (100), sky (30), window (30)
- Methodology**
- Detect temporal variations in pixels for sky, building, window, and AC units.
  - Train ML classifier models to temporal features: random forest classifier (RFC), 1-dimensional convolutional neural network (1D-CNN), and 3-dimensional convolutional neural network (3D-CNN with 10x10 aperture of spatial features plus temporal features).
  - Apply trained models to segment the scene based on sequences of IR images.
  - Extract time series of AC units.
  - Apply state-change models and change point detection methods.

- Different pixels have distinct time series characteristics depending on their types (See Figure 1).
- A pixel-level testing accuracy for RFC, 1D-CNN, and 3D-CNN model is around 85%, 87%, and 94% respectively (See Figure 2).
- Time-dependence of the source has characteristic on/off transitions that correspond to AC operations and potentially user behavior (See Figure 3).
- On/Off timings of AC unit (See Figure 4) can be extracted with change point detection techniques.

**Policy implications:** improving energy monitoring systems and providing empirical evidence of user behavior as an input to decision-making processes in energy policy.

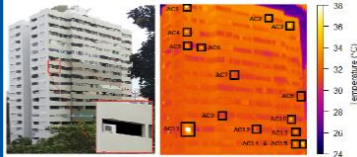


Fig 1. Left: A visible wavelength image of the exterior view of the building under study in Singapore. Right: the infrared image of the same building with annotated AC units.

Source: Pandarasamy et al. (2021)

