Infrared Thermography for Energy Behavior and Environmental Structures

Kyungmin Lee
Advisor: Dr. Gregory Dobler
Energy and Environmental Policy
Biden School of Public Policy and Administration
University of Delaware
03/08/2021

Contents

1. Background on urban thermography
2. Singapore imaging
3. IR time series for the various pixel types
4. Changepoint detection

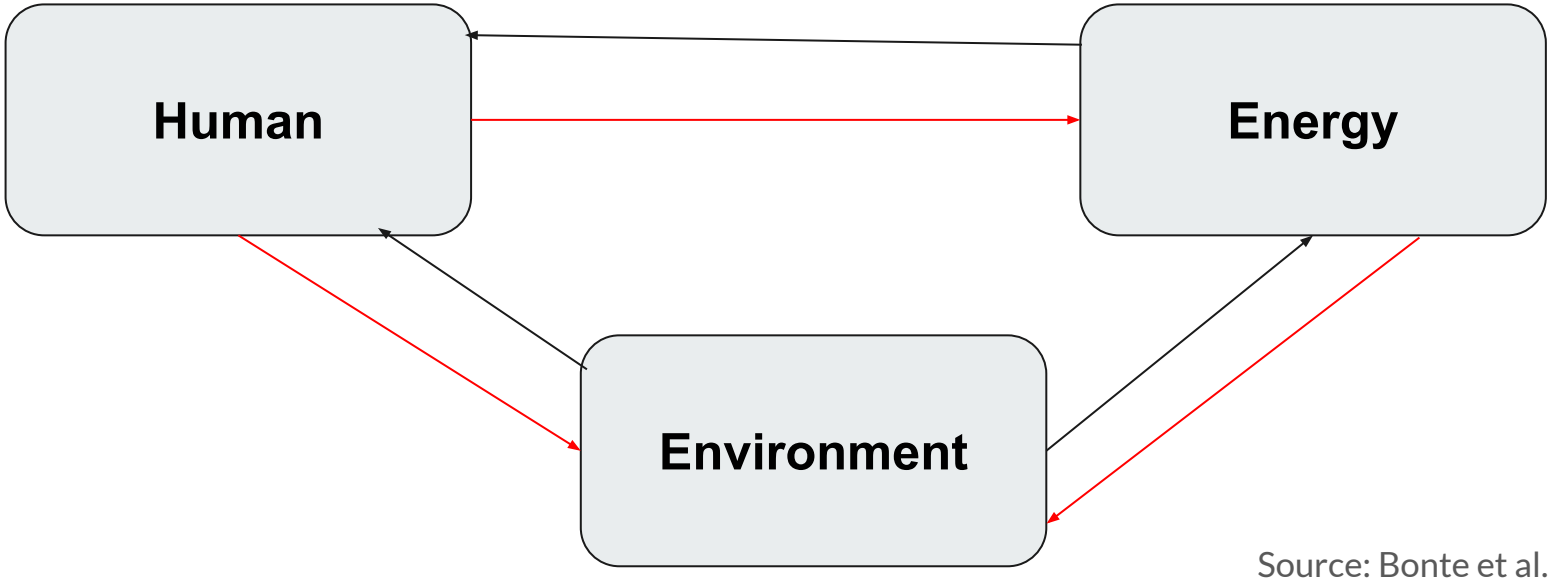
1. Background

1. Background

Heilmeier's Catechism

1) **What am I trying to do?**
   - Infrared thermography for building diagnostics
2) **How is it done today, and what are the limits of current practice?**
   - Measure energy consumption behavior and environmental structure
   - Limited to measure energy consumption behavior through thermal sensing and infrared image
3) **What's new in your approach and why do you think it will be successful?**
   - Add a new possible method of using image processing and computer vision in making evidence-based policy in energy policy field

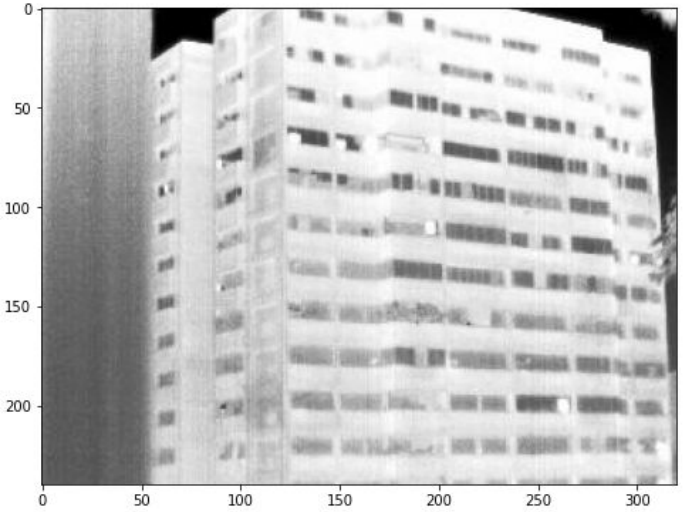
Building-occupant system modeling



Source: Bonte et al. (2013)

2. Singapore Imaging

Image



Model

Random Forest Classifier (RFC)

1-Dimensional Convolutional Neural Network (1D CNN)

3-Dimensional Convolutional Neural Network (3D CNN)

Data Sample 1

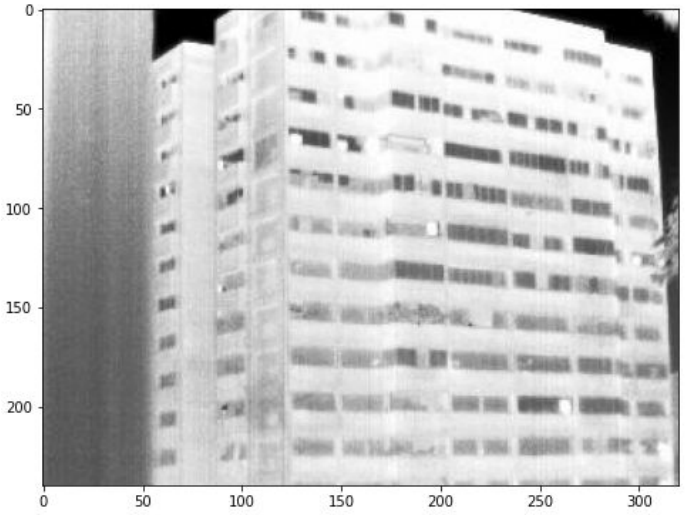
Date: 2020-03-14

Time: 00:00:00 - 04:00:00

Number of images: 1,435

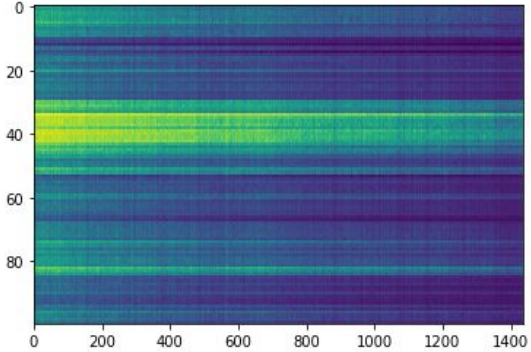
Number of features: 190

- Air Conditioner: 30
- Building: 100
- Sky: 30
- Window: 30

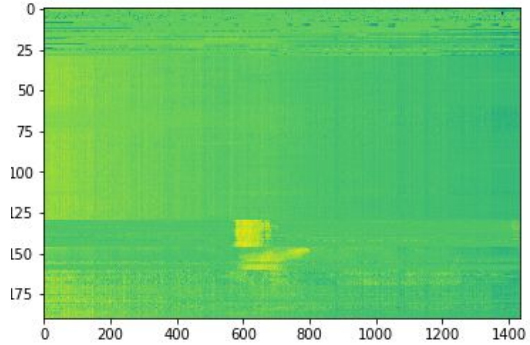


Training accuracy: 0.99~1.0
Testing accuracy: 0.91~0.96

Building feature

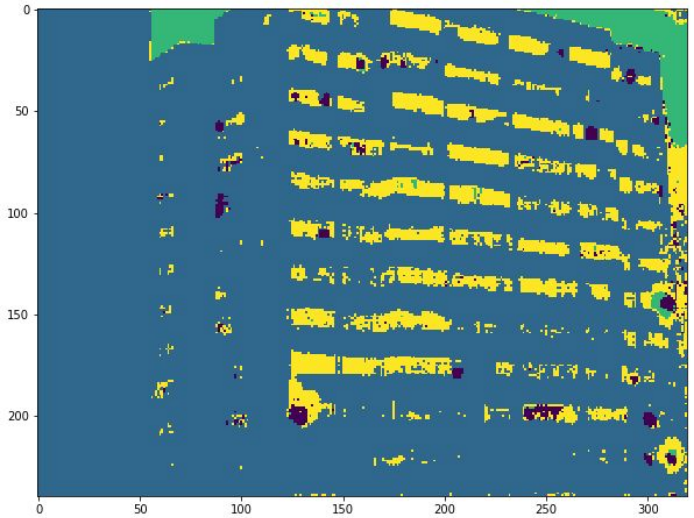


Standardized features



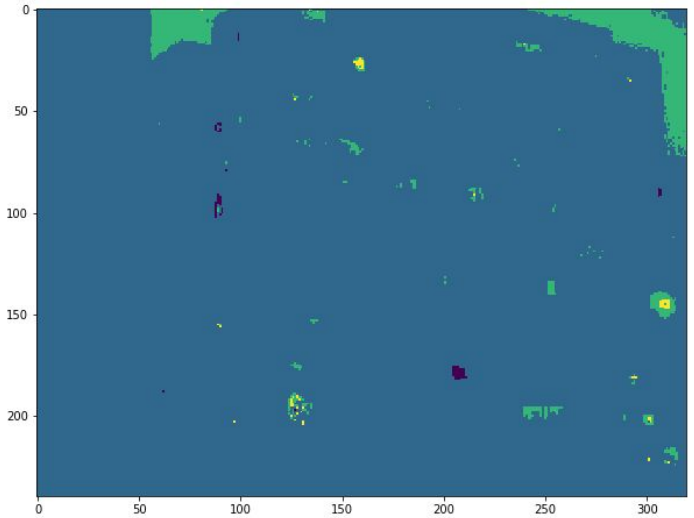
Prediction of RFC

Training accuracy: 0.99~1.0
Testing accuracy: 0.91~0.96



Prediction of 1D CNN

Training accuracy: 0.86~0.97
Testing accuracy: 0.79~0.97



Data Sample 2

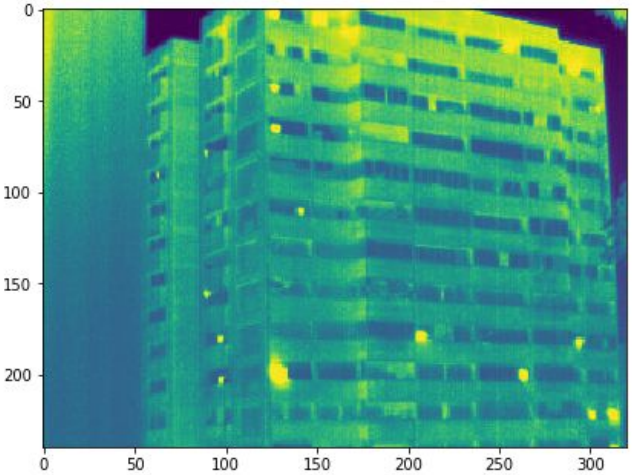
Date: 2020-03-14

Time: 00:00:00 - 04:00:00

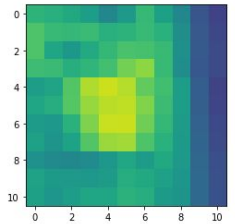
Number of images: 1,00
(the first 100 images)

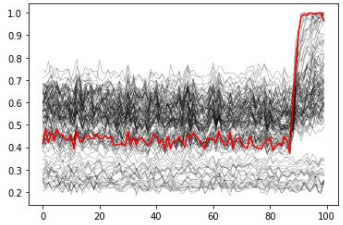
Number of features: 190

- Air Conditioner: 30
- Building: 100
- Sky: 30
- Window: 30

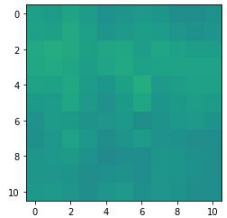


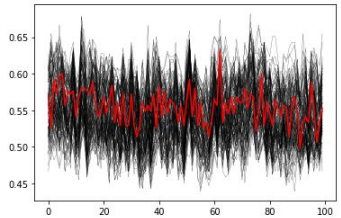
Air conditioner





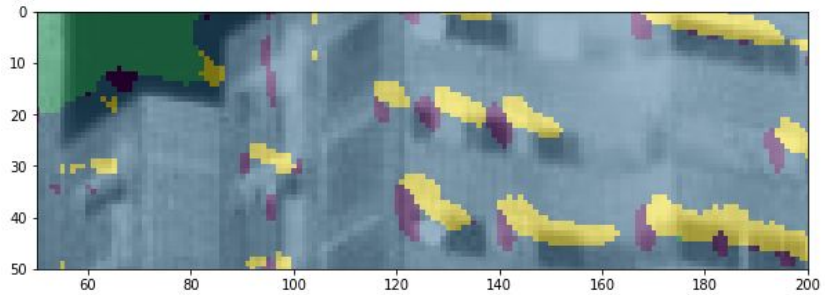
Building

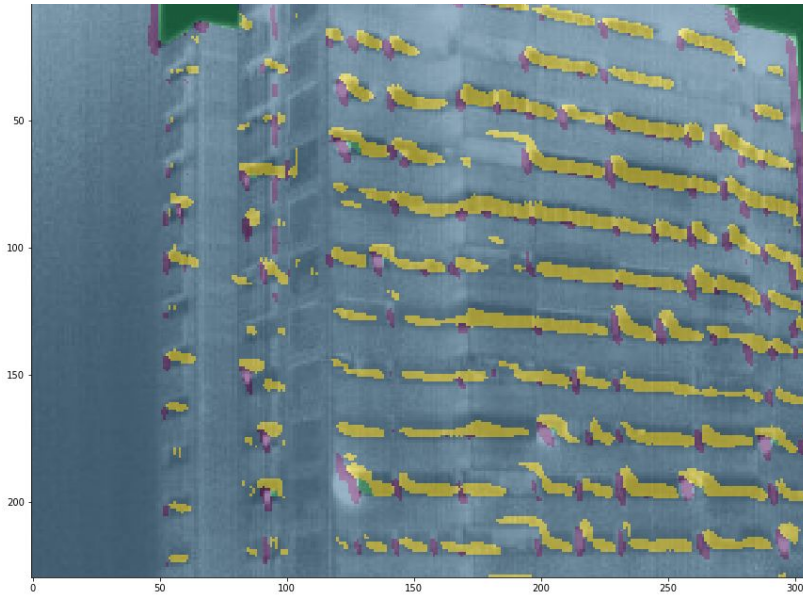




Prediction of 3D-CNN

Training accuracy: 0.97~0.99
Testing accuracy: 0.94~0.95





*Accuracy is increased when the number of image is increased to 300

Data Sample 3

Date: 2020-03-14

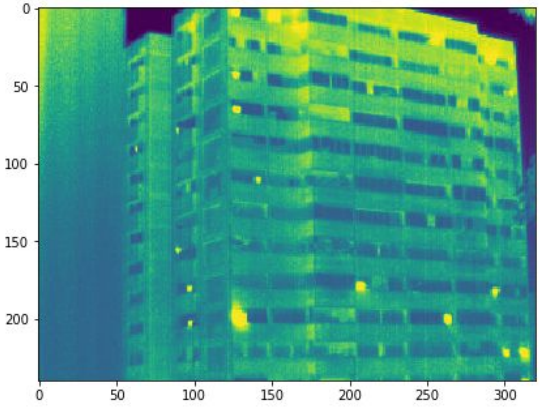
Time: 00:00:00 - 04:00:00

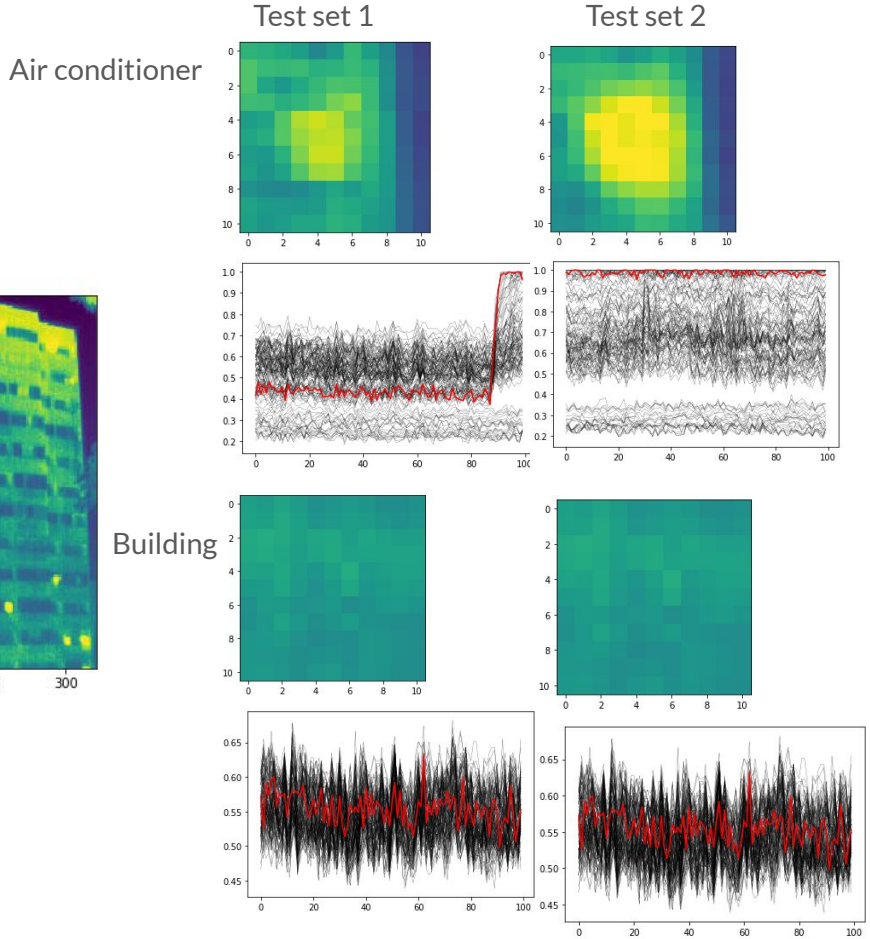
Test examples: 2 sets

Number of images:
100 for each set (200 in total)

Number of features: 190

- Air Conditioner: 30
- Building: 100
- Sky: 30
- Window: 30

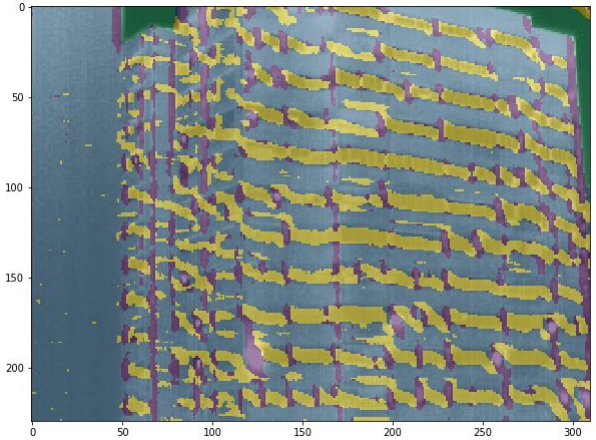




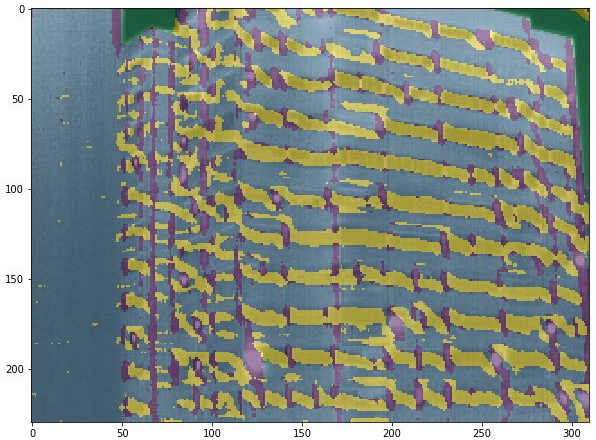
Prediction of 3D CNN - 2 test sets

Training accuracy: 0.84~0.98
Testing accuracy: 0.90~0.97

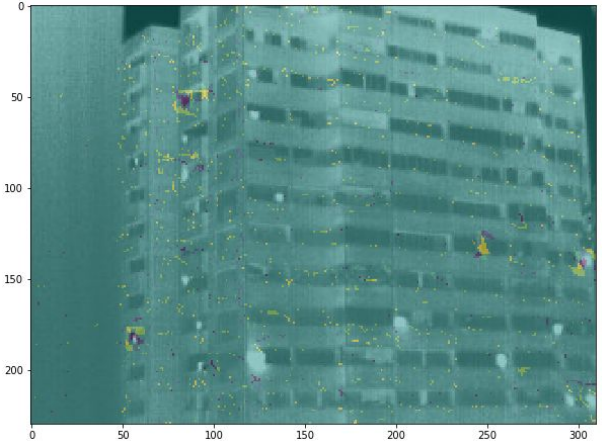
Test set 1



Test set 2



Differences



Data Sample 4

Date: 2020-03-14

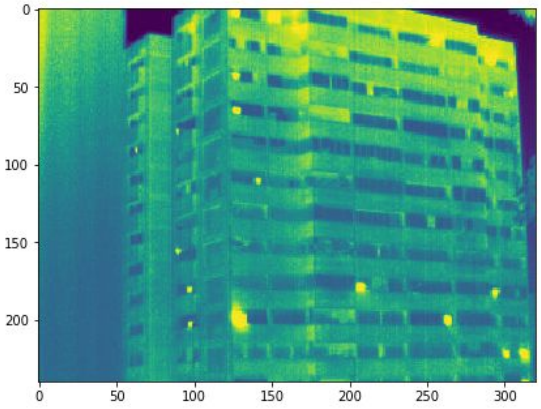
Time: 00:00:00 - 04:00:00

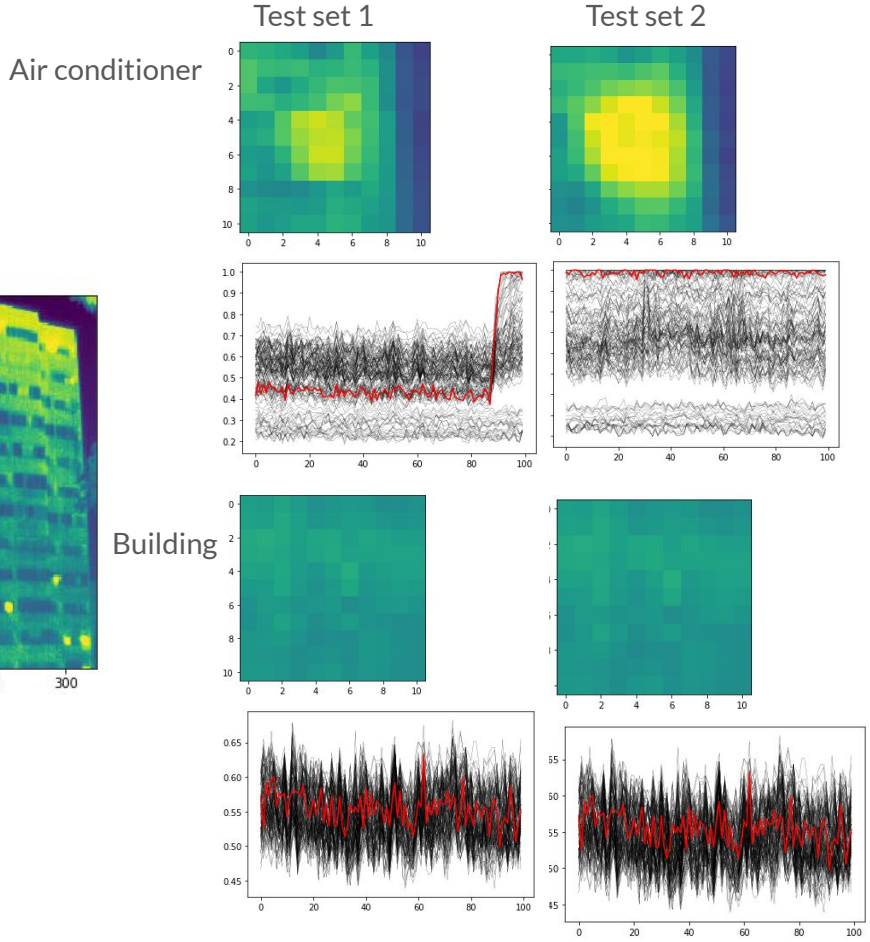
Test examples: 2 sets

Number of images:
100 for each set (200 in total)

Number of features: 360

- Air Conditioner: 30
- Building: 150 (from 100)
- Sky: 30
- Window: 150 (from 30)

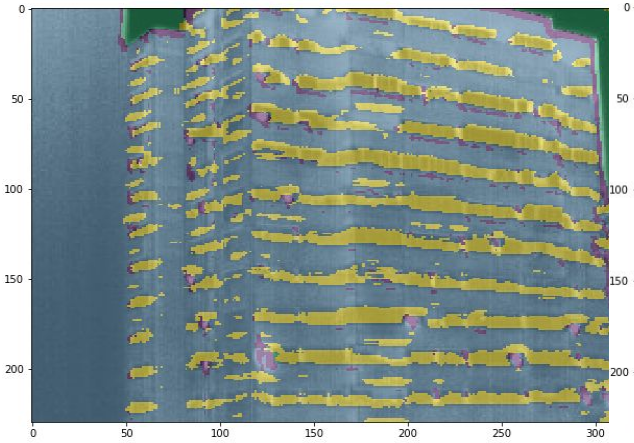




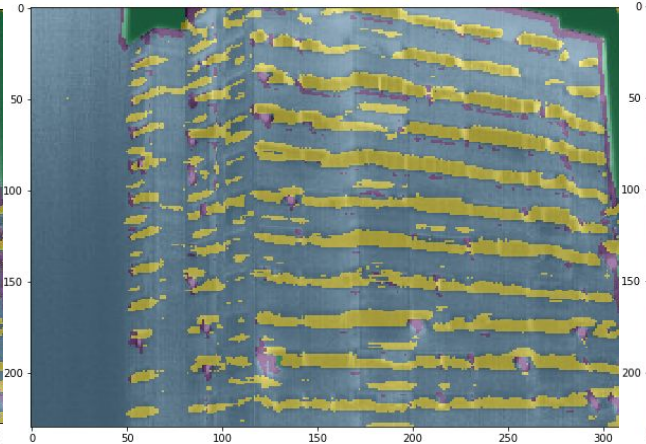
Prediction of 3D CNN
- 2 test sets
- increased labels

Training accuracy: 0.97
Testing accuracy: 0.99

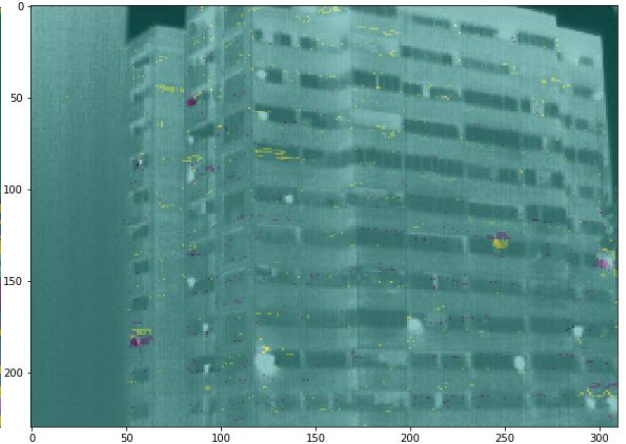
Test set 1



Test set 2

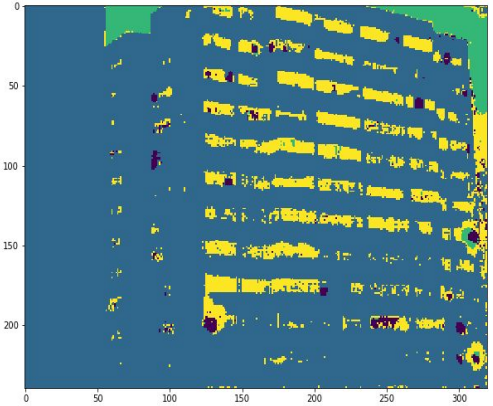


Differences

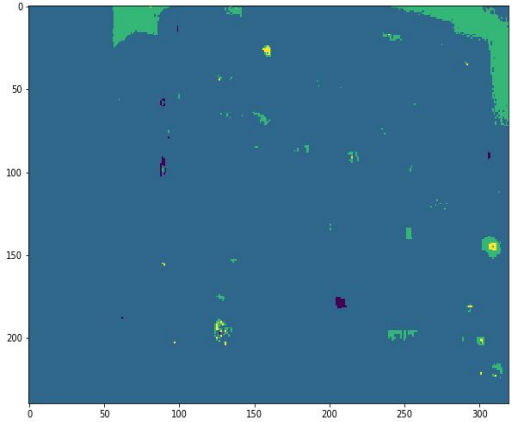


Comparison of Results

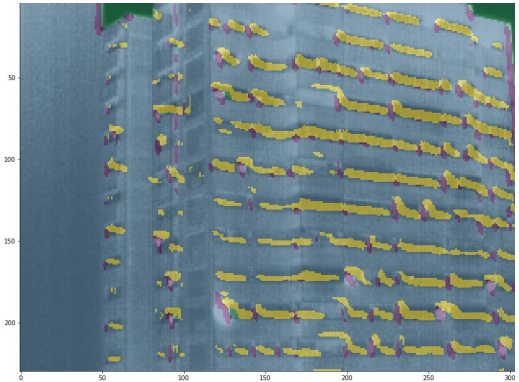
RFC



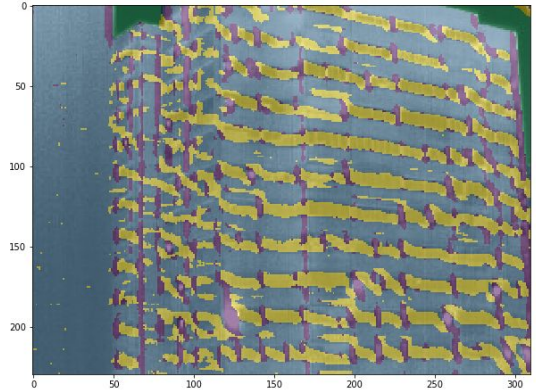
1D CNN



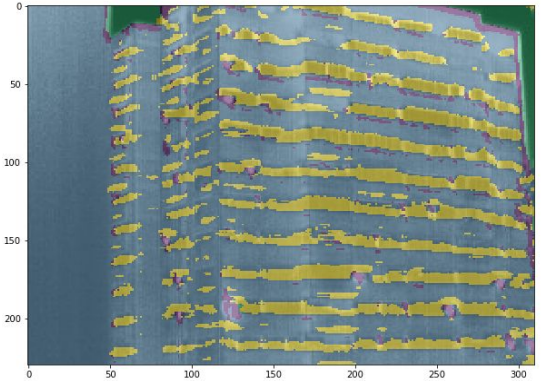
3D CNN



3D CNN (2 sets)



3D CNN (2 sets & inc. labels)



3. IR Time Series for the various pixel types

Data Sample

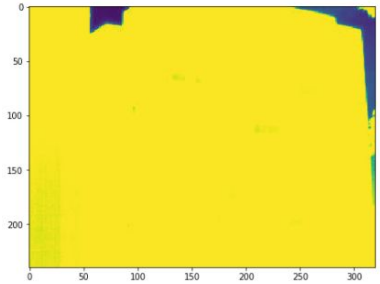
Date: 2020-03-14 ~ 2020-03-15

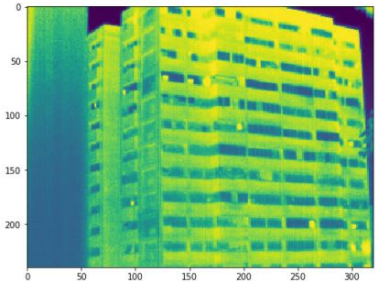
Time: 19:00:00 - 04:00:00

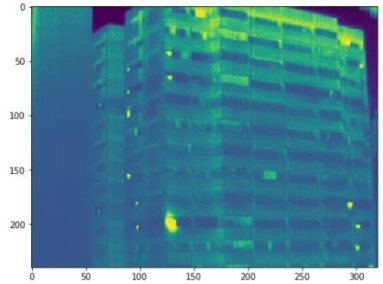
Number of images: 3,228

Number of features: 360

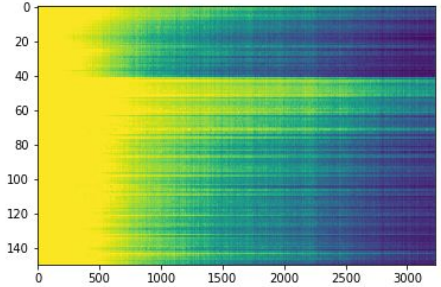
- Air Conditioner: 30
- Building: 150
- Sky: 30
- Window: 150



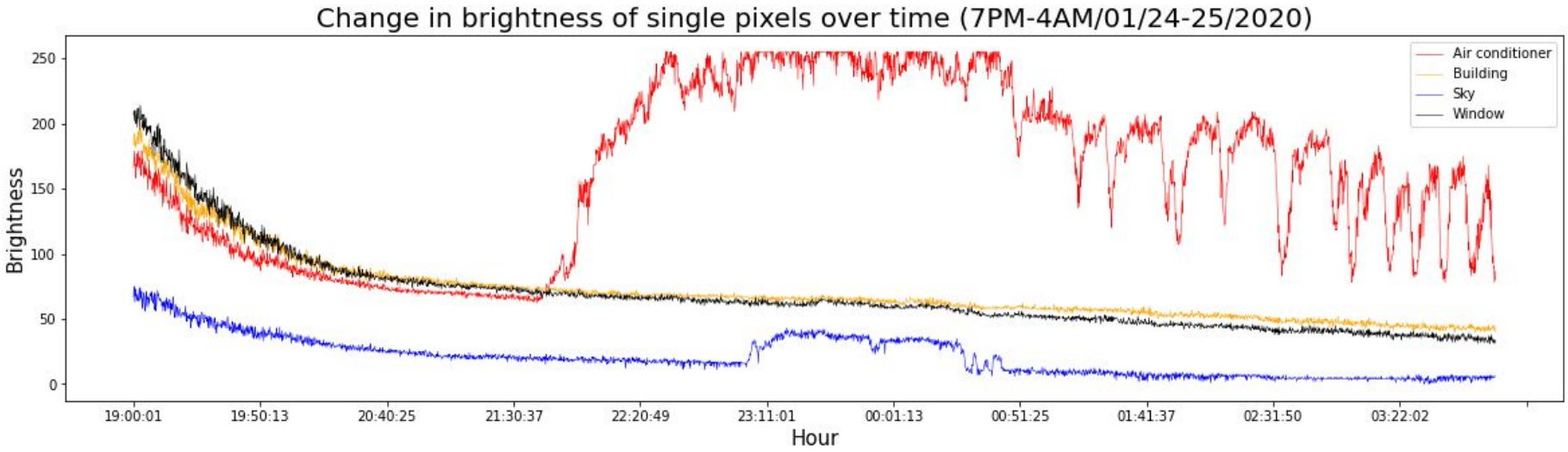




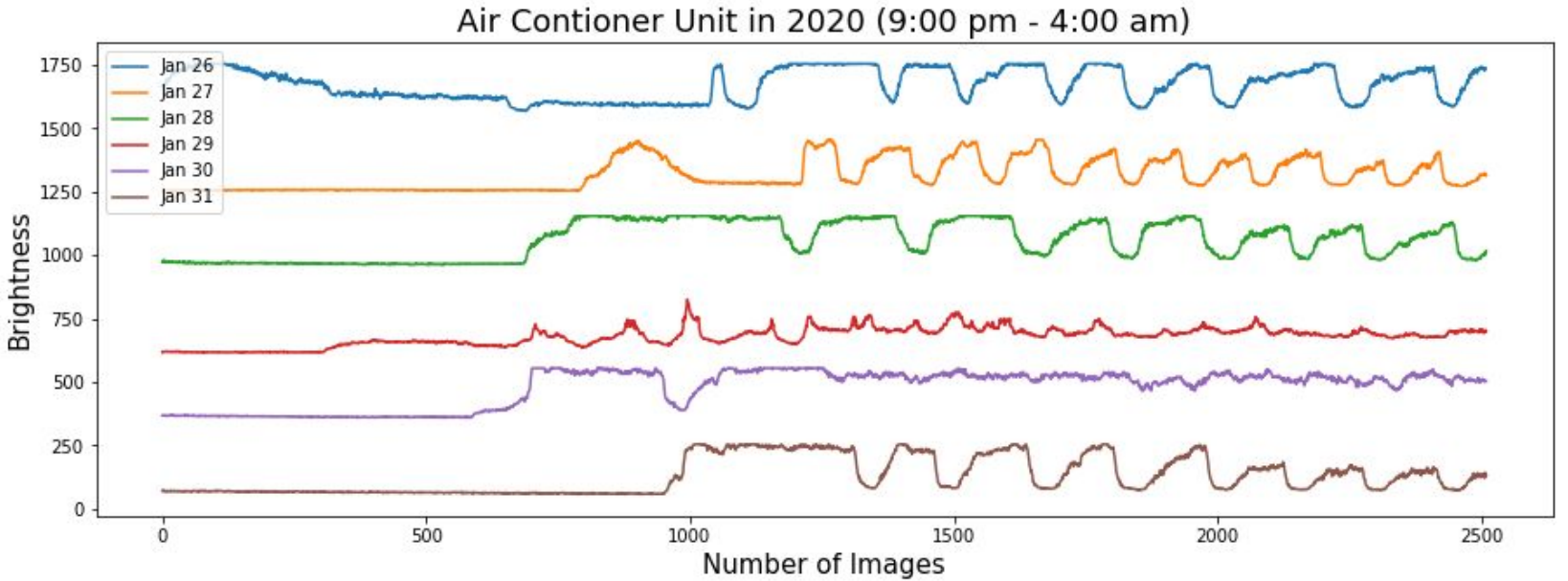
Building feature



Time series analysis



Time series analysis



4. Detect change

Data Sample

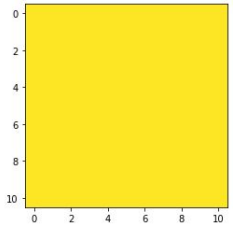
Date: 2020-01-24 ~ 2020-01-25

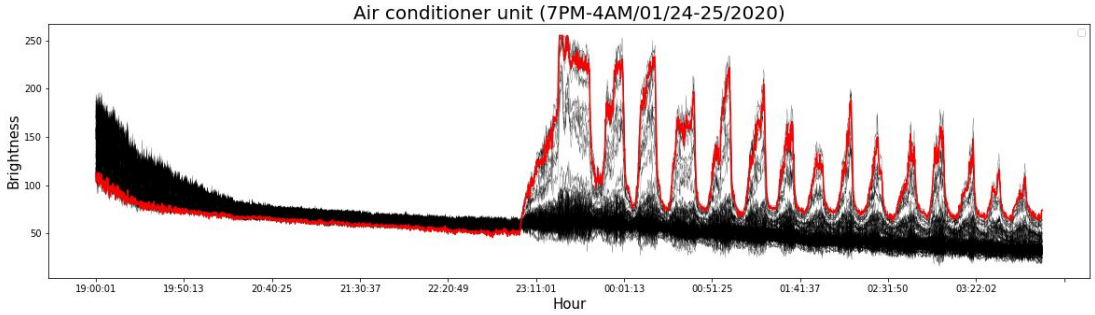
Time: 19:00:00 - 04:00:00

Number of images: 3,228

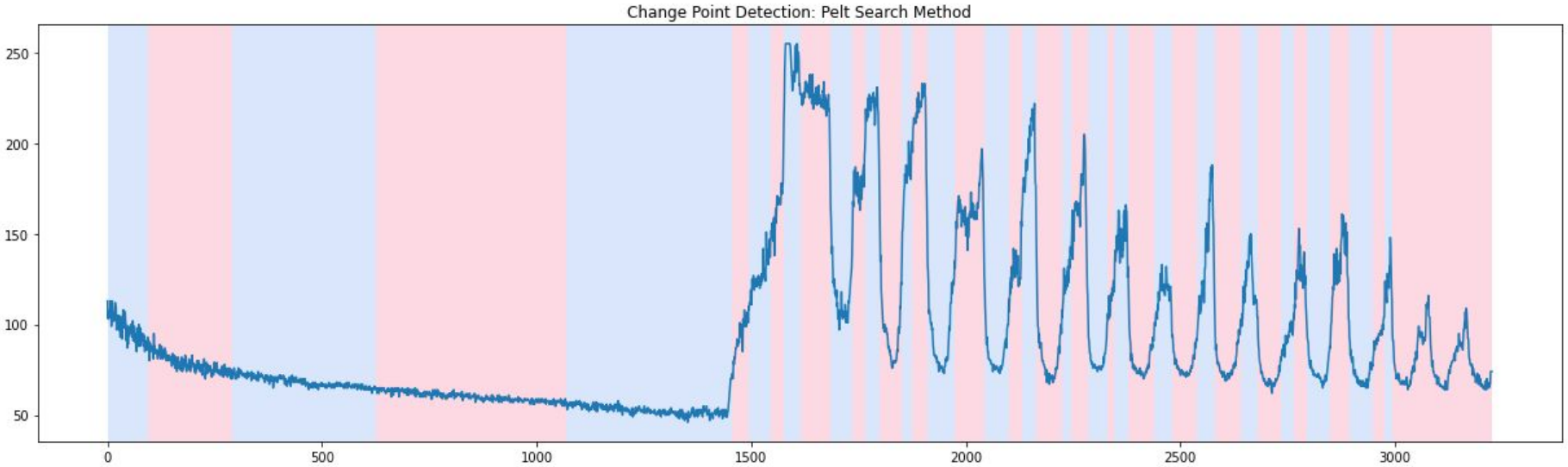
Pixel:

- Air Conditioner: 1 example (5x5 size)

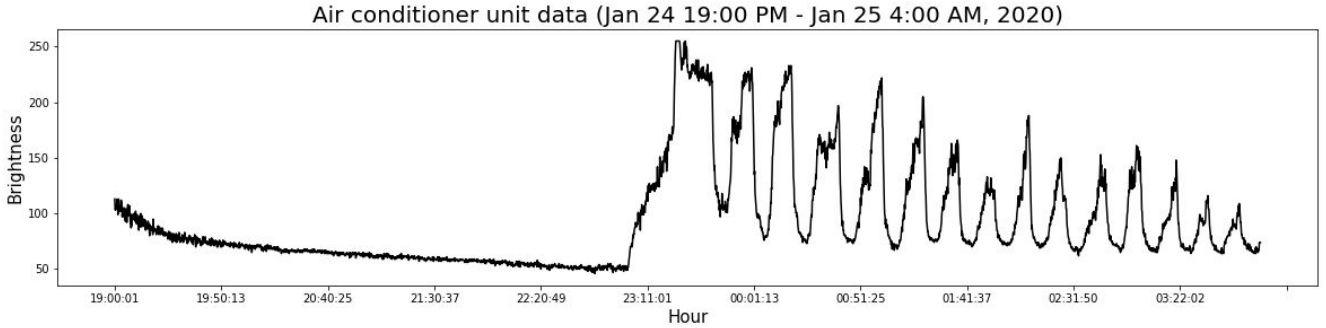


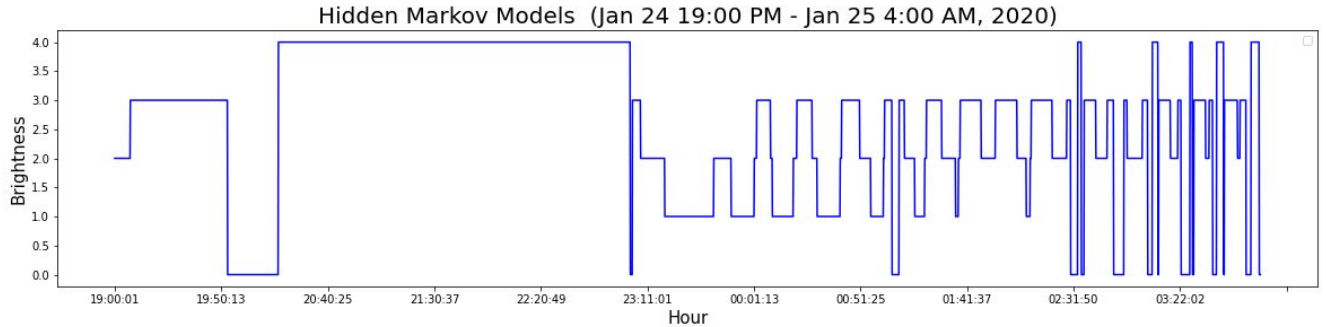


ChangePoint Detection



Hidden Markov Model (HMM)





Future Study

- Cycling normal
- Correlation of on temperature with ambient
- Anti-correlation of window temperature with AC temperature

Thank you!

1. Background

Heilmeier's Catechism

4) Who cares? If you're successful, what difference will it make?
- energy and environmental policymakers, urban policy makers, urban policy,

5) How long will it take?
- Jan 14 - Mar 15 2020 data is provided.

6) What the midterm and final exams to check fo r success?