Transfer Learning for HVAC Fault Detection

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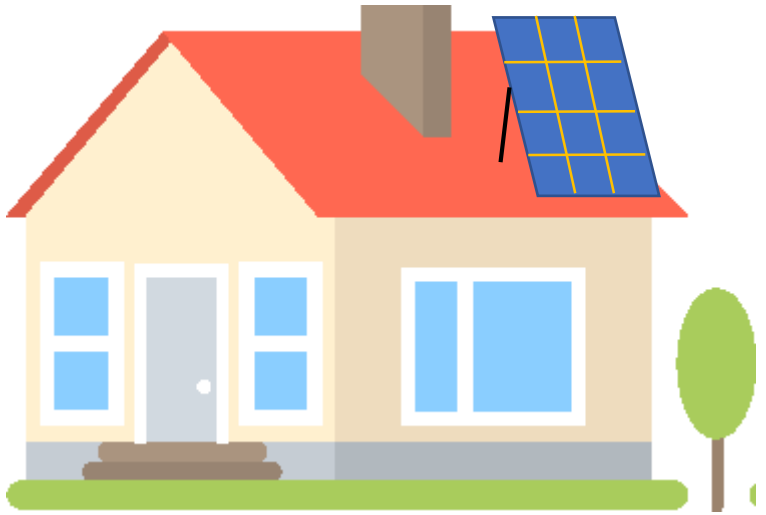
Smart Buildings

1. New buildings with smarter HVAC systems; streaming lots of performance data

2. Performance can be used to improve HVAC system efficiency w/ statistical and machine learning tools

3. Deployment of these tools require lots of ground truth data, most buildings are old and lack such data

4. Transfer learning can address this shortcoming: learn verifiable model on building with lots of data, use a small amount of data from a target building to transfer the model, rather than learning a new one from scratch



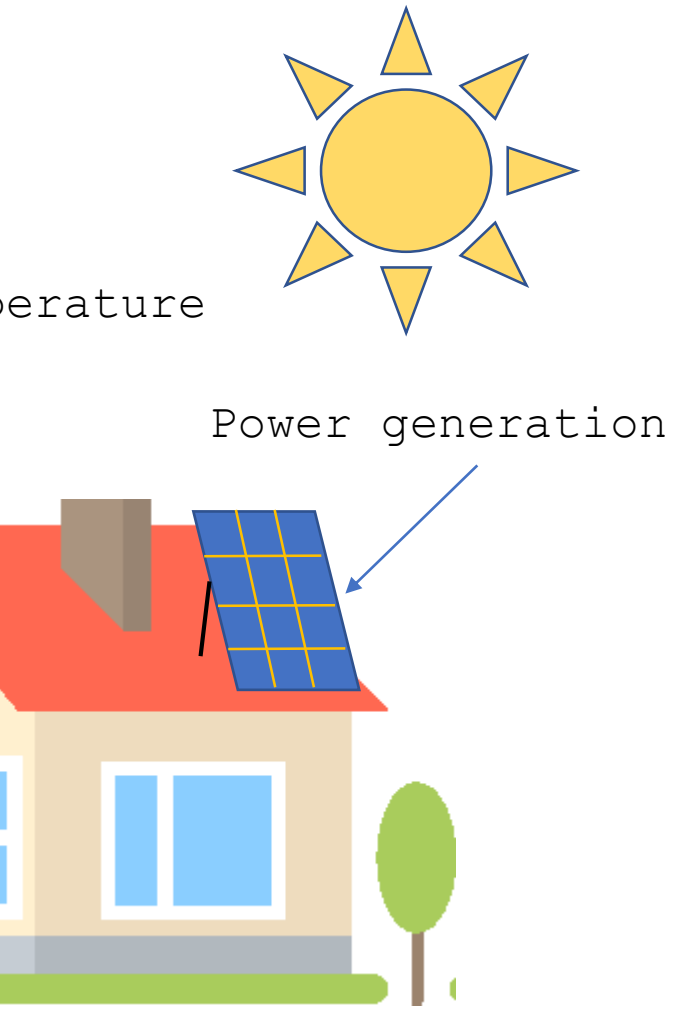
Modeling HVAC Systems

Inputs: $s_1, s_2, \ldots s_T$

Outputs: $x_2, x_3, \ldots x_{T+1}$

State Transition Model

$$x_{t+1} = As_t + \epsilon_t$$



Brown et al. (2012) “Kernel regression for real-time building energy analysis”

Fault Detection

When something breaks in the HVAC system, A is no longer an accurate model, two probabilities:

Operational

$$P(x_{t+1}|A, s_t)$$

Faulty

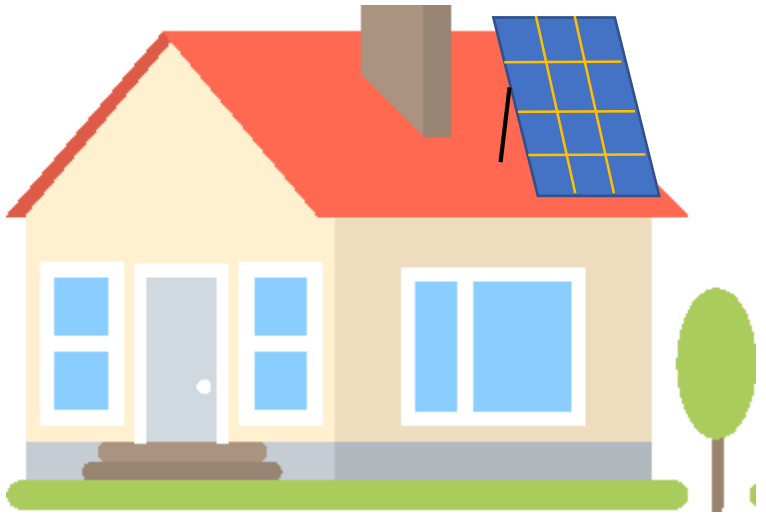
$$P(x_{t+1}|\tilde{A}, s_t)$$

Matrix normal prior with column-wise covariance on $\tilde{A}$ gives Neyman-Pearson Classifier:

$$0 \leqslant \mathrm{Tr}\left[(x - As)^T(x - As)\right] - \mathrm{Tr}\left[xx^T + AA^T - C^{-1}D^TD\right] - p\log(|C^{-1}|)$$

$$C := (ss^T + I)$$

$$D := (xs^T + A)$$



Transfer Learning

Simulated Building

- 3-story, ~50k sq ft office building
- Cool, wet climate in Seattle

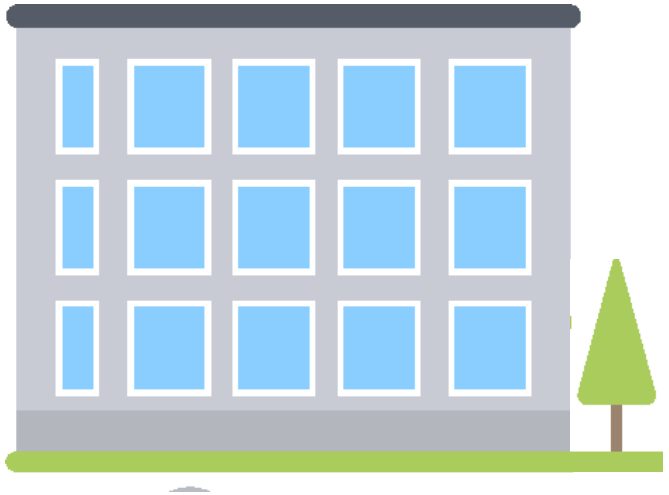
Real Building

- 2 story, ~25k sq ft office building
- Dry, arid climate in Eastern Washington

Learn model A with lots of samples

Weighted LS

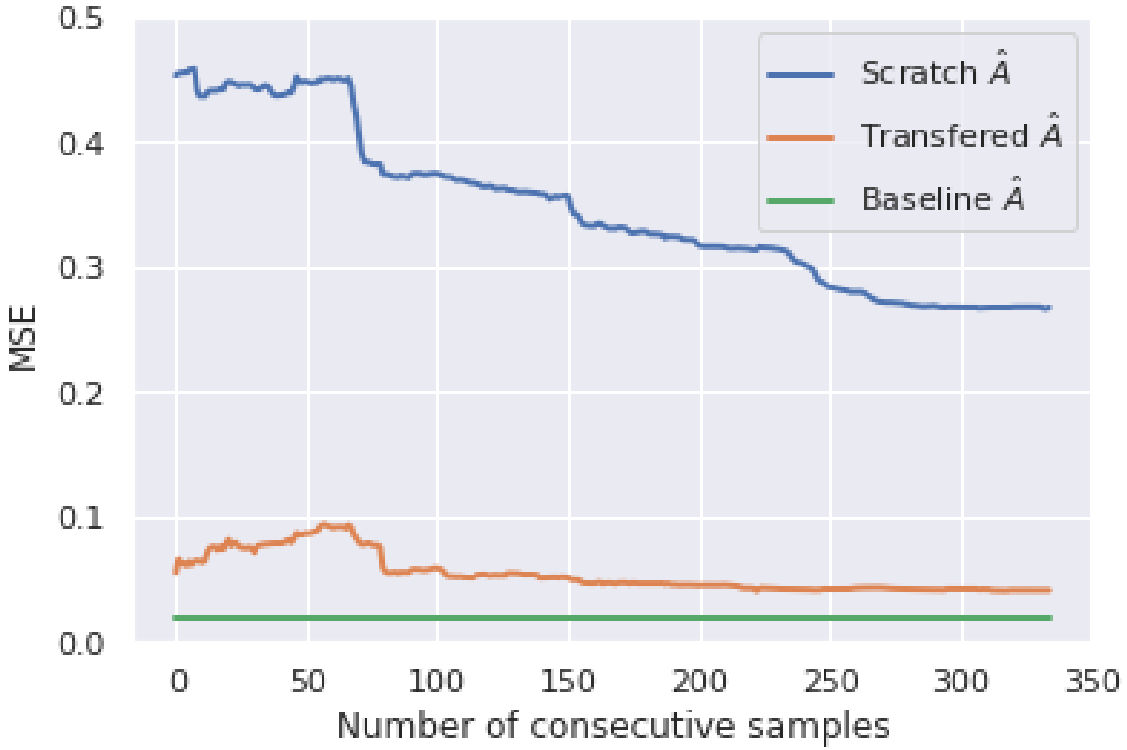
Learn model C using A as starting point



Systems Engineering Building, PNNL, Dong, J. et al. [2019] "Online Learning for Commercial Buildings"

Transfering Fault Detection

Loss of Model C on real building



Classification performance trained on 2 weeks of data