Modeling TCL via DTMC

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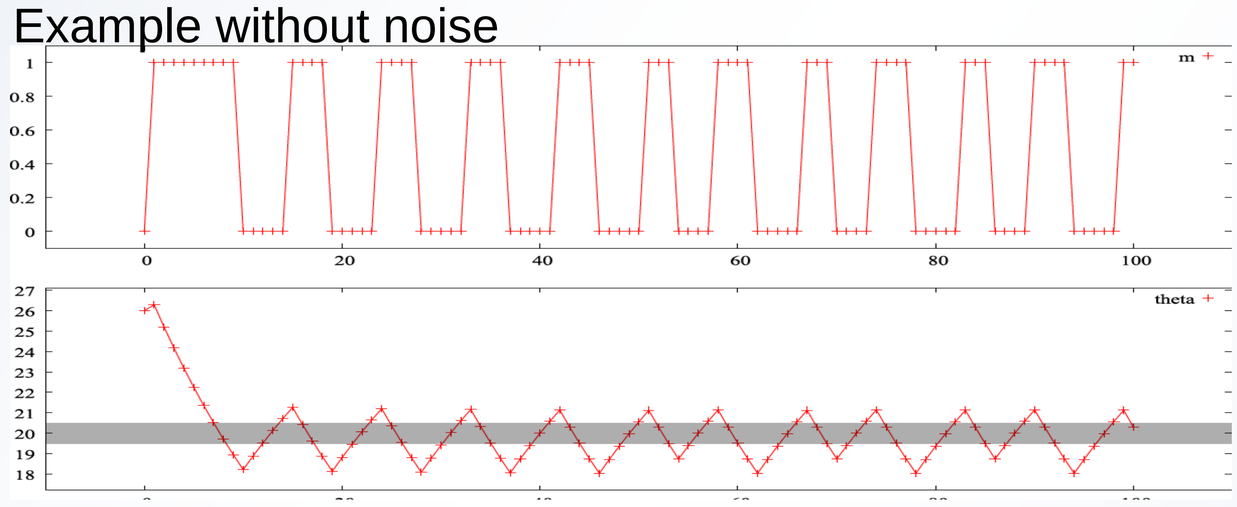
▶ Temperature Controlled Loads (Malhame, Callaway)

$$\theta_i(t_{n+1}) = a_i\theta_i(t_n) + (1 - a_i)(\theta_{a,i} - m_i(t_n)R_iP_i) + \mathrm{w_i(t_n)}$$

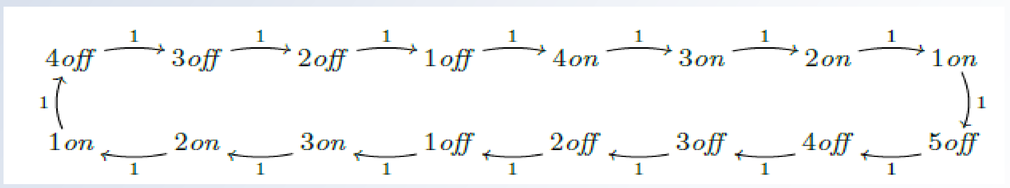
- $\theta_s = 20°C$ Set temperature
- $a = \exp(-\frac{h}{CR})$ Governs thermal mass
- $R = 2\ \frac{°C}{kW}$ Thermal resistance
- $C = 10\frac{kWh}{°C}$ Capacitance
- $\sigma = 0.01°Cs^{-\frac{1}{2}}$ Noise standard deviation

Example without noise



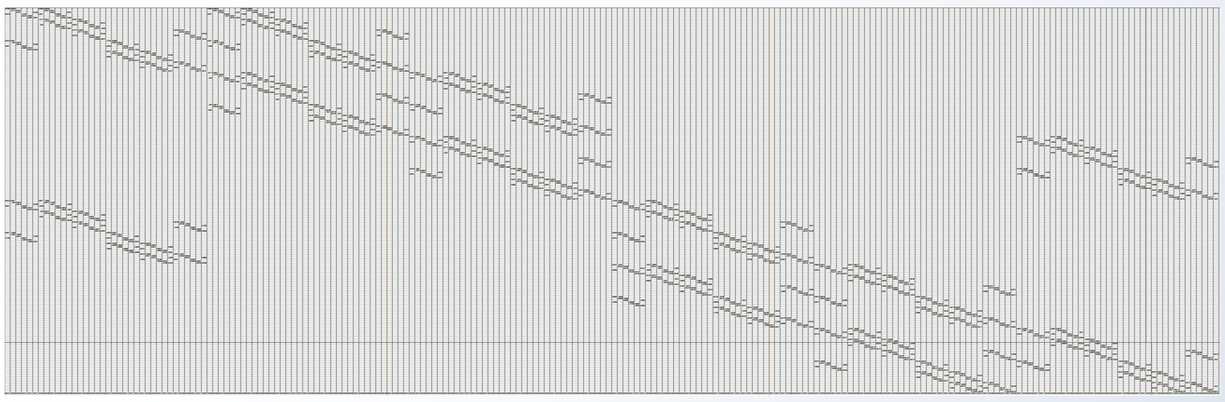
▶ System Model ➔ Transition Systems ➔ Lumping

- Bin θ (with noise)
- Evaluate $p(\theta_i, \theta_j)$ via simulation



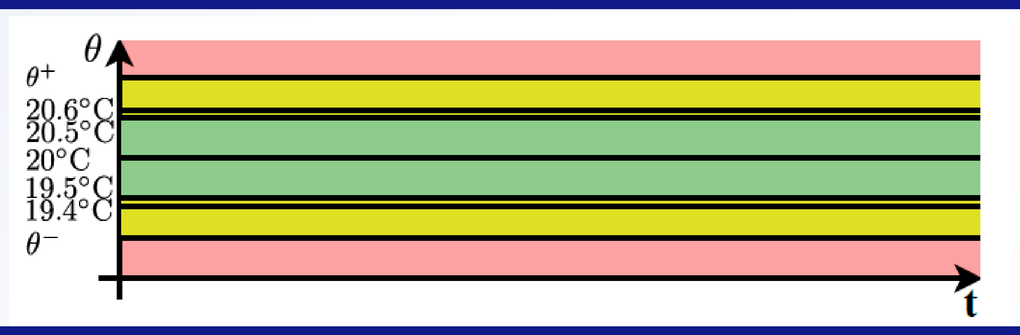
- Models DTMC of one household
- Now assume set of homo-/ or heterogeneous households
  - No control (yet)
  - Shared resources (energy/supplier grid)
- Compose population via cross product over matrices
- Reduce complexity with lumping

- 1. Order DTMC by similarity
- 2. Compose and lump successively
  - Exploit strong probabilistic bisimilarity first,
  - then, relax to weaker probabilistic bisimilarity until composed DTMC becomes tractable



Homogeneous population leads to sparse matrices

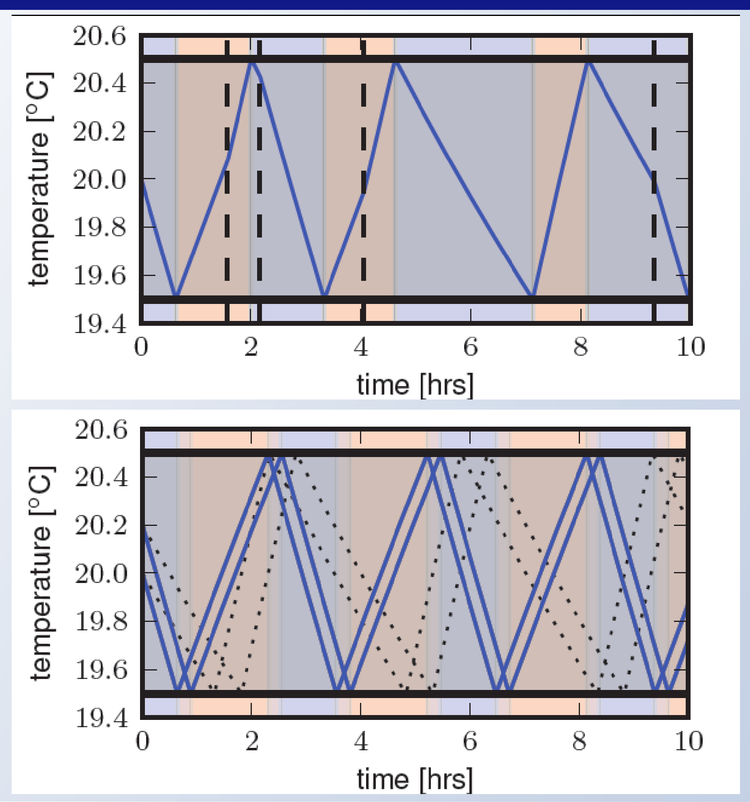
▶ Analysis



- Severity of *safety* violation: $\theta_t - \theta_s \pm \delta$
- Prioritize households
- Minimize weighted violation

▶ Future Focus

- Equidistant time discretization becomes event based
- Dynamics of bounds (upper/lower bound)
- Increase number of bins
- Add control
  - Then, households not independent anymore, i.e. control feedback
  - Yet, noise influence still is independent
  - Control energy vs. energy
- Include noise in resistance term by windows/doors
- Determine inaccuracy induced by weak prob. bisim.



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