Occupant Thermal Comfort Models

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Thermal comfort

Motivation

- Thermal comfort influence productivity and performance of individuals in offices.
- Can personal thermal comfort be learned and control be designed based on occupants adjustments in a ventilated space?

Objective: To develop a surrogate of thermal discomfort based on the sum of magnitude adjustments made by the occupant and use it for learning-based control.

Existing methods & Challenges:

- Empirical methods: Predicted Mean Vote (PMV) uses Fanger's equation, Actual Mean Vote (AMV), and Predicted Percentage dissatisfied (PPD).
- Models: Artificial neural networks (ANN), Autoregressive and hybrid autoregressive ANN-models, fuzzy, Models for indoor air temperature prediction, Other ANN variants etc.
- Personal comfort systems & models: Environmental factors, behavioural parameters, physiological parameters, and others (dress, time etc) have been proposed recently.
- The thermal comfort in most of these models is understood from human perception through surveys or based on various measurements.

Proposed Approach

- Compute thermal comfort as adjustments made to a device controlling the local thermal space (e.g., fan) for the occupied duration.
- Record the adjustments made to the comfort device in terms of magnitude, time etc.
- Record also other factors such as temperature, air-speed, relative humidity etc.
- Hypothesize discomfort using Discomfort Index (DI) as:

$$DI = \frac{\sum |adjustments|}{Occupancy\ Duration}$$

- The sum of magnitude of adjustments over occupied time is a surrogate of discomfort.
- The DI provides a Personal Comfort Model without having to rely completely on surveys or performing numerous measurements.
- Model human behaviour using first-order model plus switching function as:

$$\frac{dy(t)}{dt} + a_i y(t) = k_i u(t),\ S(t) = \sum_i \tau_i\, \xi_{[\tau_i, \tau_{i+1}]}(t)$$

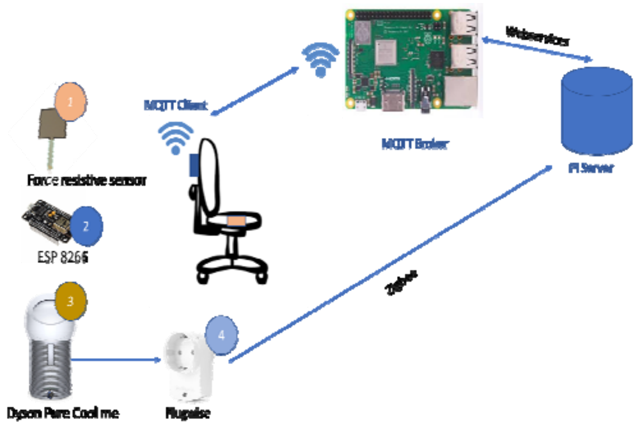
- Approximate the model from y = Temperature, u= fan power input, record the ON, OFF timings and conditions.

- Fix k and estimate 'a' using:

$$a_i \mid [\tau_i, \tau_{i+1}] = \frac{k \int_{t_0}^{t} \theta\, u\, d\theta - ty + t_0 y(t_0) + \int_{t_0}^{t} y\, d\theta}{\int_{t_0}^{t} \theta\, y\, d\theta}$$

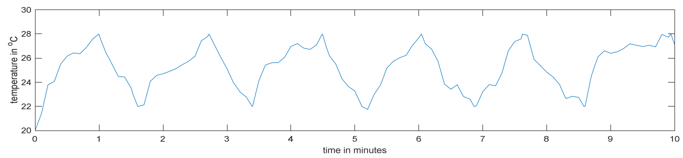
- Adjust 'k ' iteratively to reduce the model error.

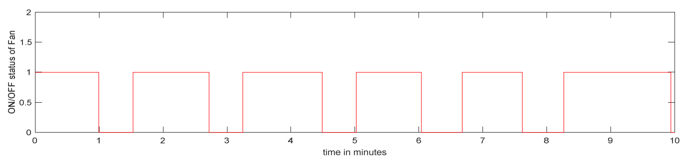
IoT Architecture

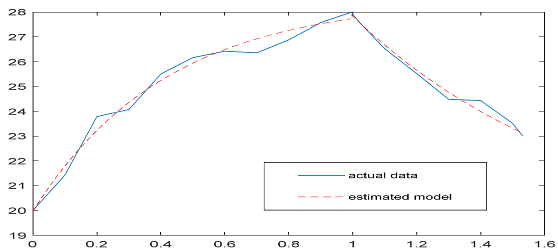


Results

- Simulation results for a typical thermal zone with fan being turned ON/OFF of by the occupant and the model fitted using the proposed approach is shown.
- The first order model shows a reasonable approximation of human interaction on the environment.







Conclusion

- A novel approach for modelling human comfort model & human interaction with the thermal zone is proposed using a first order plus switching function.

"This research project is funded by the National Research Foundation Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme."

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