**Genie: A Longitudinal Study Comparing Physical and Software Thermostats in Office Buildings**

Bharathan Balaji, Jason Koh, Nadir Weibel, Yuvraj Agarwal

University of California, San Diego Carnegie Mellon University

Can We Supplant Old Thermostats with Software Apps?

- **Thermostat Unusability**
  - Occupant discomfort
  - Energy inefficiency
  - Complaints to building manager

- **Retrofitting is expensive**
  - Each thermostat replacement costs ~$1000

- **Thermostat Problems**
  - Slider doesn’t provide temperature
  - No access on weekends
  - Accidental blocking of thermostat
  - No feedback to building manager
  - No energy information

How does it work?

- **Genie** based on RESTful Web Services. It is built using open source BuildingDepot and BACnet stack.

Deployment

- **CSE EBU3B Building at UC San Diego**
  - 150,000 sqft., constructed in 2004
  - 1 AHU, 236 thermal zones, 4794 points

- **Genie Status**
  - Active since October 15, 2013
  - >220 registered users
  - >4500 user actions recorded

- **Study comparing Genie & Thermostats**
  - Analysis from Oct, 2013 to June, 2015
  - 32 survey respondents, 9 interviews

Thermostats vs Genie

- **Users more comfortable**

  - Digital control of the temperature is very, very useful. Moving the slider (on the thermostat) still leaves a lot of uncertainty as to what exactly will happen, and the temperature setting helps

  - Temperature changes using thermostat and Genie across all zones. Thermostats have an mean deviation of ±3.5°F and Genie has ±2°F.

  - Energy comparison between zones that use Genie and those that don’t. Energy difference is statistically insignificant.

  - 45% of users actively engaged

Table: User engagement with Genie over 21 months

<table>
<thead>
<tr>
<th>User Types</th>
<th>One-time</th>
<th>Short-term</th>
<th>Sporadic</th>
<th>Consistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Users</td>
<td>24.6%</td>
<td>30.3%</td>
<td>23.8%</td>
<td>21.3%</td>
</tr>
</tbody>
</table>

**User Feedbacks Led to Fault Identification**

- Thermostat blocked, heating malfunction
- 30 faults diagnosed from user input

Design Lessons for Software Thermostats

- Software should be in sync with thermostat
- Provide clear feedback and adequate control