Finding Small Changes Using Sensor Networks

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Outline

- Background and Motivation
- Our Experiment
  - Prototype sensor nodes
  - Finding “small changes” using a sensor network
- Conclusion / Discussion
Background

Ubiquitous Computing

“Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives.”
- M. Weiser

Smart Environment Assists Daily Life

- actualized by small sensors and networks
- Not only factories and hospitals but also home and office.

Target:
context-aware applications in home and office
Motivation

- Context-aware applications need “contexts”
  - In home and office, hard to abstract “contexts” because a system might observe various behaviors that relate to many objects.

- We describe contexts based on small changes of sensor data captured by sensor nodes attached to objects.
“Small changes” in Sensor Data

Advantages:
- Easy calculation using low CPU power
- Possible to pack data into small packets (better for network load)

Disadvantages:
- Discarding wave characteristics
- Need to add knowledge to data (small changes and sets)

Apply several of time windows and check small changes

Calculate change probabilities and co-change probabilities
Experimental Setting

Sensor floor system

Chair with sensor node

Door with sensor node

Sensor node

Sensor floor system
Prototype Sensor Node

1) Prototype sensor nodes attached to objects in office

Prototype Sensor Node

XPort Ethernet Controller
Accelerometer
Infrared Sensor
Illuminometer
Thermometer, Hygrometer

with embedded CPU H8/36049HG (ROM 96 K, RAM 4K, 10MHz)
Sensor Data

2) Store sensor data on server disk  (sampling rate is about 10Hz)

3) Capture small changes in sensor data
### Change Probabilities of One Sensor

Change and co-change probabilities of chair sensor data

<table>
<thead>
<tr>
<th>Changed sensor</th>
<th>Acc.</th>
<th>Infrared</th>
<th>Illuminometer</th>
<th>Acc. • Infrared</th>
<th>Illumi. • Acc.</th>
<th>Infrared • Illumi.</th>
<th>Acc. • Infrared • Illumi.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time window (sec.)</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>30</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerometer</td>
<td>.346</td>
<td>.533</td>
<td>.591</td>
<td>.618</td>
<td>.669</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrared sensor</td>
<td>.023</td>
<td>.050</td>
<td>.070</td>
<td>.092</td>
<td>.139</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illuminometer</td>
<td>.002</td>
<td>.014</td>
<td>.030</td>
<td>.044</td>
<td>.086</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acc. • Infrared</td>
<td>.013</td>
<td>.041</td>
<td>.062</td>
<td>.085</td>
<td>.128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illumi. • Acc.</td>
<td>.002</td>
<td>.012</td>
<td>.025</td>
<td>.072</td>
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</tr>
<tr>
<td>Infrared • Illumi.</td>
<td></td>
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<tr>
<td>Acc. • Infrared • Illumi.</td>
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</tr>
</tbody>
</table>

A chair is moving.  
→ An individual is sitting

Finding events by analyzing sequences:  
Infrared, then Acc.  → An individual sat.  
Acc., then Infrared  → An individual left.
Co-change Probabilities among Sensors

Change and co-change probabilities of sensor data of chair, door, and floor

<table>
<thead>
<tr>
<th>Changed Sensor</th>
<th>1</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair</td>
<td>.346</td>
<td>.532</td>
</tr>
<tr>
<td>Door</td>
<td>.008</td>
<td>.017</td>
</tr>
<tr>
<td>Floor</td>
<td>.063</td>
<td>.107</td>
</tr>
<tr>
<td>Chair · Door</td>
<td>.002</td>
<td>.013</td>
</tr>
<tr>
<td>Door · Floor</td>
<td>.001</td>
<td>.004</td>
</tr>
<tr>
<td>Floor · Chair</td>
<td>.026</td>
<td>.079</td>
</tr>
<tr>
<td>Chair · Door · Floor</td>
<td>.001</td>
<td>.02</td>
</tr>
</tbody>
</table>

Hints for contexts:
- Door moved, then chair moved → Individual started working
- Chair moved, then door moved → Individual left office

Inferring distance between objects:
\[ \text{distance}(\text{chair, door}) > \text{distance}(\text{chair, floor}) \]
Conclusion / Discussion

- Preliminary results:
  - Small changes translated into contexts by adding object and situational knowledge

- Discussion
  - Index of change probabilities
  - Is “small change” sufficient?
  - How large of knowledge is necessary?
  - How many sensor nodes in an office?