Object Motion MITes

Emmanuel Munguia Tapia
Changing Places/House_n
Massachusetts Institute of Technology
Object motion MITes

GOAL: Measure people’s interaction with objects in the environment

We consider that someone uses an object whenever the person has been in direct contact with the object by manipulating it either by touching, moving, or holding it.
Passive RFIDs
Passive RFIDs

Problems: (1) metal objects, (2) alignment between reader and tag, (3) battery life and (4) wearable glove is intrusive
Magnetic Reed Switches

Problems: (1) Installation is complicated and time consuming and (2) not possible to install in every object
Vibration/Tilt sensors

Problems: (1) Sensitivity to motion cannot be adjusted and (2) orientation sensitive.
Summary of challenges

- Installation complexity
- Installation time
- Sensitivity to motion
- Orientation dependence
- Battery life
- Wearable technologies are intrusive
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Measure people’s interaction with objects in the environment

- Stick-on and forget devices
- Single sensor (2-axis accelerometer) to measure movement, tilt, and vibration
- Active RFID tags that sense movement
- Low cost ~$29
- Wireless at 2.4GHz
- Tx/Rx range 106m outdoors line of sight and 38m random disposition,
nRF24E1 MCU + Transceiver

24AA320 EEPROM Memory

Microstrip Antenna

ADXL210 MEM Accelerometer

24AA320 MEM Accelerometer

nRF24E1 MCU + Transceiver

Crystal 16MHz
MITes measure dynamic acceleration (movement and vibration) as well as static acceleration (rotation and inclination)
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Algorithm running inside MITes to detect movement
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Installation procedure for stick-on MITes
Object Motion Installation
Object Motion Installation

In some objects, RFID tags would just not work!
Problem 1: Adjacencies

- Sensors in the neighborhood of the moved sensor/object will fire

- We need a way to distinguish between “real motion” and “adjacent motion”

Not a simple problem!
Classification problem: real vs. adjacent motion

<table>
<thead>
<tr>
<th>Object</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawer</td>
<td>50</td>
</tr>
<tr>
<td>Drawer adjacent</td>
<td>50</td>
</tr>
<tr>
<td>Cabinet</td>
<td>50</td>
</tr>
<tr>
<td>Cabinet adjacent</td>
<td>50</td>
</tr>
<tr>
<td>Door</td>
<td>50</td>
</tr>
<tr>
<td>Couch</td>
<td>50</td>
</tr>
<tr>
<td>Couch adjacent</td>
<td>50</td>
</tr>
<tr>
<td>Chair</td>
<td>50</td>
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<tr>
<td>Table</td>
<td>25</td>
</tr>
<tr>
<td>Cup</td>
<td>25</td>
</tr>
<tr>
<td>Remote control</td>
<td>25</td>
</tr>
<tr>
<td>Toilet cover</td>
<td>25</td>
</tr>
<tr>
<td>Faucet</td>
<td>25</td>
</tr>
<tr>
<td>Bed</td>
<td>25</td>
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Acceleration signal for ‘opening a drawer’

- X normalized signal
- Y normalized signal
- Noise threshold
Features extracted

1. Min value above noise threshold
2. Max value above noise threshold
3. Area under curve
4. Duration of the motion (number of samples greater than the noise threshold)
5. Average of the signal
6. Variance of the signal
Classification algorithms

<table>
<thead>
<tr>
<th>RULE BASED ALGORITHMS</th>
<th>TREE-BASED ALGORITHMS</th>
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</thead>
<tbody>
<tr>
<td>1. ZeroR</td>
<td>1. Decision stump</td>
</tr>
<tr>
<td>2. OneR</td>
<td>2. J48</td>
</tr>
<tr>
<td>3. Rules PART</td>
<td>3. NB tree</td>
</tr>
<tr>
<td>4. Single conjunctive rule learner</td>
<td></td>
</tr>
<tr>
<td>5. Ridor</td>
<td></td>
</tr>
<tr>
<td>6. Jrip</td>
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</tbody>
</table>

Why these?

They generate a set of simple decision rules that can be easily implemented as if-then clauses in a microprocessor.
Results

• Best feature to use is the duration of motion.
• Best algorithm to use is Rules PART which generates the simple classification rule

PART decision list

xy_duration > 4: real
xy_duration <= 3: adjacent
Real vs. Adjacent motion trade-off
Problem 2: Battery life

Based on our experiments, we have found that the minimum sampling rate for distinguishing adjacencies is 10Hz

- At 10Hz, battery life is 46 days
- At 20Hz, battery life is 23 days

Problem 3 false positives are high
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Piezofilm sensor

WAKEUP CIRCUIT

Extreme low power circuitry

Sleeping (power down mode) unless motion in external sensor is detected
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- New battery life is 6.3 years (theoretical) but at least 1 year in practice based on measurements.

- False positive activations is close to zero as measured over 21 days.