Tools for Ubiquitous Computing Research

MIT House_n Consortium

Place Lab:
Proactive Health
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House_n
Massachusetts Institute of Technology
Outline

• Motivation: Health care crisis
• House\_n research agenda
• House\_n Tools for studying behavior
  – The PlaceLab living laboratory
  – Portable kit of sensors (MITes)
Some statistics

From the 2000 census of population

- Nearly 1 in 5 U.S. residents suffer some kind of disability
- Approximately 40% of people 65 and older have a disability
- Over 20% require continuous monitoring and help performing activities of daily living (ADLs)
Some statistics

From the 2000 census of population

- In 2030, nearly one out of two households will include someone who needs help performing basic ADLs
House\_n research agenda

Goals

• Increase the time that people remain healthy, independent and safe in the comfort of their homes.
• Enable novel context-sensitive applications to be built and piloted
Health care interventions

**Three levels** (in increasing order of difficulty and importance):

1. **Responding to crisis** (requires a few good sensors) → **Medical staff**
2. **Early warning of emerging problems** (requires ubiquitous sensors) → **Changes in behavior** (dementia/independence)
3. **Proactively keeping people healthy** (requires ubiquitous sensors & communication) → **Encouraging healthy behavior**
Current work: proactive health

- **Switch/bend sensors**
  - Doors
  - Cabinets
  - Drawers
  - Thresholds
  - Appliances
  - Objects

- **Wearable sensors**
  - Accelerometers
  - Heart rate monitor
  - Self report

- **Multi-purpose sensors**
  - People-locator tags
  - Auditory sensors
  - Optical sensors

- **Activity recognition**
  - Eating meals
  - Talking
  - Sleeping patterns
  - Taking medications
  - Cleaning
  - Cooking
  - ...

- Detect **change** in activity;
  - Motivate behavior changes

New ML algorithms

Health applications
House_n tools:
The PlaceLab Living laboratory
PlaceLab

- Is not to show off “new technology”
- It is a residential observational research facility

Goals
- Run different research studies
- Real people living at PlaceLab 24/7 (weeks/months)
- Collect necessary data for doing research

Design constraints
- Reliable sensing infrastructure
- Add/remove sensors on the fly (Modular)
Why another live-in laboratory?

Our design benefited from lessons learned by those who created prior “living labs”:

- Georgia Tech Aware Home (Abowd, Mynatt, and others)
- UVA’s Smart Home Monitor (Alwan)
- Smart House (Matsouoka)
- Welfare Techno House (Suzuki)
- Philips HomeLab
- Sleep laboratories
- Others…
Why another live-in laboratory?

The PlaceLab combines these unique characteristics:

- A unified, extensible, multi-modal, and truly ubiquitous sensor and observational infrastructure
- Designed for shared data generation/distribution and collaboration
- Sensors integrated into architectural aesthetic
- Genuinely live-in
Goal: Context-aware technologies at home

Three key challenges (among others):

1. Need for complex, naturalistic environments
   *Simulated behavior is overly simplistic*

2. Need for comprehensive sensing
   *Activity occurs throughout environment; realistic datasets costly to obtain; head-to-head comparisons*

3. Need for labeled training datasets
   *Many context-recognition algorithms need labeled example data; annotation required for evaluation*
Testing ubicomp technology in the home

Ethnographic/HCI research

Laboratory prototyping

Larger n, in-home studies

Innovative design ideas
The PlaceLab: filling a gap

Ethnographic/ HCI research → Laboratory prototyping → The PlaceLab → Pilot Data → Design insight → Important questions → Innovative design ideas

Larger n, in-home studies
PlaceLab can complement...

- Surveys and interviews
- Experience sampling
- Direct observation
- Portable kits of sensors for in-home studies
- Demonstration labs
- Short tests in parts of live-in labs; tests with limited sets of sensors
The PlaceLab Infrastructure
PlaceLab

A lower floor unit of full-service condominium building.

The apartment can be entered both from the lobby and from the side yard.
Interior entrance
Living room
Living room

• Most visible technology a standard TV
Living room
Kitchen

- Apartment allows the study of natural home behavior

- Interested in complex behavior such as
  - Decision making
  - Interruptions
  - Searching
  - Communication
Sensor integration

- Sensors blend into aesthetics of environment (so easy to ignore)
Kitchen
Office
Bedroom
Master bath
Microcontroller; connections server closet
Speakers
Optional: CO2 sensor
Optional barometric pressure sensor
Humidity sensor
Temperature sensor
IR video camera
Color video camera
Top-down counter camera
Light sensor
IR illuminators
Microphone
Switches to detect “open/close”
Temperature sensor
Subwoofer

Embedded sensors

Emphasis on ubiquity and quantity over quality

Reasonable locations
Easy access to sensor infrastructure
Wireless object movement MITes

- Real-time, wireless transmission
- Receivers scattered throughout apartment
- 100-200 sensors depending on task
MITes sensors installation

Installation procedure for stick-on MITes

Single point of contact, no multi-point alignment is required
Object usage MITes
Activity recognition from sensors in the environment

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparing lunch</td>
<td>59%</td>
</tr>
<tr>
<td>Toileting</td>
<td>71%</td>
</tr>
<tr>
<td>Preparing breakfast</td>
<td>45%</td>
</tr>
<tr>
<td>Bathing</td>
<td>87%</td>
</tr>
<tr>
<td>Dressing</td>
<td>64%</td>
</tr>
<tr>
<td>Grooming</td>
<td>89%</td>
</tr>
<tr>
<td>Preparing a beverage</td>
<td>36%</td>
</tr>
<tr>
<td>Doing laundry</td>
<td>86%</td>
</tr>
</tbody>
</table>

Activity detected at least once criteria
Example sensor data
RFID reader wristband

Determine motion when holding an object

Measures: RFID tagged objects + wrist acceleration
Range: 10cm
Cost: ≈ $181 US

Based on Intel Research Seattle RFID glove (Perkowitz ETAL ’04)
And in collaboration with Ambient Intelligence MIT Media Lab
Wireless limb accelerometers and HR

- Real-time, wireless transmission
- Receivers scattered throughout apartment
- Up to 5 locations
- HR monitor (Polar chest strap)
Activity recognition from wearable sensors

Activity recognition from wearable accelerometers

- 5 points
  - Right hip
  - Dominant wrist
  - Non-dominant upper arm
  - Dominant ankle
  - Non-dominant thigh
Recognition results for 20 activities

- Walking 89.7
- Sitting & relaxing 94.8
- Standing still 95.7
- Watching TV 77.3
- Running 87.7
- Stretching 41.4
- Scrubbing 81.1
- Folding laundry 95.1
- Brushing teeth 85.3
- Riding elevator 43.6
- Walking carrying 82.1
- Work computer 97.5
- Eating/drink 88.7
- Reading 91.8
- Bicycling 96.3
- Strength train 82.5
- Vacuuming 96.4
- Lying down 95.0
- Climbing stairs 85.6
- Riding escalator 70.6

Using decision trees and leave-one-subject out crossvalidation
Subject self report

- Random or context-aware self-report sampling on phone (activities, mood and other states of mind, etc.)

- Apps on phone can respond to PlaceLab sensors

- Standard surveys or ethnography can also be used
<table>
<thead>
<tr>
<th>Device</th>
<th>Room Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microprocessor</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Camera</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Top down camera</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Microphone</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Wireless receiver</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Gas flow</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Water flow</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
<tr>
<td>Switch sensor (wired &amp; wireless)</td>
<td>Living Room, Study, Bedroom, Kitchen</td>
</tr>
</tbody>
</table>
Automatic selection of most informative audio-visual views using motion and camera location heuristics
Control “closet”
Running an experiment

- Recruit participant(s)
- Participant(s) move in
- Home disconnected from Internet (data saved to portable disk)
- Minimal interaction with researchers during stay
- At end of stay, data is collected and stored
- Data annotated for items of interest
- Datasets become more valuable as more researchers annotate them
Recruiting

Teach MIT Researchers about Your Everyday Life

Ever get the feeling that today’s technologies and homes are not designed for you and the way you live? Help MIT researchers design better technologies and homes (with fewer frustrations!) by sharing your everyday experiences.

Live in a comfortable one bedroom apartment for 10 days. Researchers will capture your activities and experiences and apply lessons learned to developing technologies for better health and living.

For more information, contact Jason at placelab-volunteers@mit.edu or (617) 452-5679

PlaceLab AN MIT + TIAX INITIATIVE

House_n
Take away

• The PlaceLab is a live-in residential home laboratory developed for health and ubiquitous computing research

• Unlike prior facilities, the home has a truly ubiquitous, synchronized, and multi-modal sensor infrastructure built non-obtrusively into the architecture

• The lab can be used as a hypothesis generation and testing facility and can help projects transition from laboratory testing to larger-\(n\), in-home studies with portable sensors

• We are trying to operate the facility as a shared resource
Thank you!

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