Lab-of-things in Research and Education

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Acknowledgements: Ryan Robucci, Sandy McCombe-Waller, Susan Fager, Buz Chiemlewski, Sami Rollins
Lab-of-things from my perspective

Uniform programming abstraction

Lab-of-things

- Z-wave
- Custom Sensors
- Kinect

rapid prototyping tool
central management tool for home deployments
helps me focus on my research
Lab-of-thing in a wide spectrum of research and education

- Home Energy Management Research
- Wearable Computing Research

Smart Home Automation Course
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Smart Home Automation Course
Towards Net-zero homes

- Off-grid: Solar, wind, hydro
- Grid inter-tied: solar, wind, hydro
- Grid-only: pay electricity bill

Energy gap

Net-energy

Net-zero
Towards Net-zero homes

Energy budget 2-3x less than grid-only

Question: how do we bridge this gap?
- more energy efficient technology
- usage behavior changes

First Step: Collect real data

Automating Energy Management in Green Homes
N. Banerjee, S. Rollins, K. Moran, ACM Homenets 2011, Best Paper Award, CCR 2011
Measurement infrastructure Using Lab-of-things

Home component
- Data collection
- Appliance Control
- Home OS
- Vera2 driver

Server component
- java servlet webserver
- extensive REST API
- database

Appliance Control
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- Vera2 driver

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Sensors that we support in our deployment

- **zwave**
- MicroRadar™ micro-radar

For activity recognition
Data collected till date

Data from 8 homes (continuous data from 6 homes)
  - off-grid and grid-tied (4), grid-only (4) [4 GB of data]
  - <total home energy, generation, consumption, appliance>
  - 6 more off-grid and grid-tied homes have shown interest
Research Problems we worked on

• Understanding energy consumption predictability to better demand management.

• Understand ties between context and energy consumption
  - Rule mining engine that associates context with device-level energy consumption

• Energy management and indoor air quality issues in low income communities in Baltimore City
  - Planning a 20-home deployment this year
Lab-of-thing in a wide spectrum of research and education

Home Energy Management Research

Wearable Computing Research

Smart Home Automation Course
Motivation: Assistive Care devices are Cumbersome and Expensive

Interview-based study on the usability of these systems
10 patients (SCI, TBI, Scleroderma, GB)*

*It was wireless, which, the idea was good, but how it was implemented it was just a big clutter of stuff -- SCI patient [sip-n-puff nurse calling system]

*I could switch the TV on...usually took a while.. The channels went up and I couldn’t adjust the volume -- on the laser-based TV control system

Non-intrusive wearable sensors for environmental control

Wheechair pads

Pillow covers

Clothing

Gesture Recognition

Environmental Control

(Controlling appliances, nurse calls, making 911 calls)
Using Lab-of-things

Lab-of-things

Home Hub (Home Automation)

Bluetooth

Zwave

TV

Lamp

micro controller

Signal Processing

Wearable Sensors

Allows focus on the core research component
Hardware Prototype

Data processing unit

Iron-on capacitive array

Conductive thread ribbon

Embroidered capacitive patches

Wearable Capacitance-based Gesture Recognition
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Home Energy Management Research

Wearable Computing Research

Smart Home Automation Course
Using Lab-of-things for Classroom Teaching

- Taught a “Systems for Smart Home Automation” course
  - Spring 2014
  - 20 students (mix of graduate and undergraduate)
  - Computer Science and Computer Engineering majors
  - All material available: [http://www.csee.umbc.edu/~nilanb/teaching/691](http://www.csee.umbc.edu/~nilanb/teaching/691)

- Use lab-of-things as the platform for teaching home automation
  - Initial learning curve for C# and .Net concepts like .Net remoting, System.AddIn, WCF.
  - Final project where students had to demonstrate their learning through a demoable Lab-of-things project
Syllabus divided into four modules

Cloud storage, web services, Remote access

Working with actual sensors
[z-wave, cameras, kinect, energy meters, .Net Gageteer]

Basics of HomeOS (core of LoT)
[Applications, Drivers, Scouts, ports, roles, Application domains]

Basic of C#, .Net concepts
[WCF, System.AddIn, Unsafe Code, Attributes]
Sample Projects
Summary feedback on Lab-of-things

• Positive Feedback
  - System itself is very robust. our deployments have worked with minimal glitches
  - Technical support is very good thanks to the Lot team
  - Very frequent updates to the source tree

• Room for improvement
  - Education: initial confusion on how the different modules interact with each other --- scouts, platform, driver, and the App. More documentation on core technical aspects like WCF, System.AddIn
  - Community support needs to grow. E.g., Drivers for Bluetooth devices.
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Hierarchical Signal Processing Algorithm

Simple classification based on the magnitude of the match from every stage below

Micro-controller

wakeup

Template matching using FIR filter

Pairwise diff

Pairwise diff

Pairwise diff

Pairwise diff

Pairwise diff

Pairwise diff

Capacitance 1

Capacitance 2

Capacitance 3

Capacitance 4

Sensors