Automation Team Research Review

Calem Bendell, Shalon Liu, Han Yang Zhao, Michael Golfi, Loren Peter Lugosch
Hyvedev, McGill University
calem.bendell@mail.mcgill.ca

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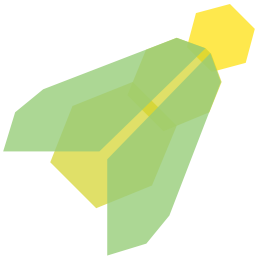
Abstract

The automation team has already made the majority of the decisions it needs to make through research and some experimentation. The automation team, known as HyveDev outside of the Solar Decathlon context, is exploring loose partnership with Equipmind, Sensorica,



HyveDev

1 Glossay of Terms

HyveDev HyveDev is the name for the automation team outside of Solar Decathlon.

Sensorica Sensorica is an Open Value Network of multidisciplinary professionals, amateurs, and it is a company with which HyveDev will potentially be working very closely.

Equipmind Equipmind is a company that is undertaking several power management and monitoring projects including behavioural modification experiments similar to the kind HyveDev has been discussing since its inception. Whereas HyveDev's behaviour modification is inspired by the Venus Project, Equipmind is inspired specifically by energy savings.

SensorStacks SensorStacks is a joint project by Sensorica and Equipmind to provide an easy to use sensor and monitoring system with an online dashboard and freemium analytics. and affiliated research labs, providing sensing and automation solutions.

Tactus Technology Tactus is a human interaction corporation, specialising, as its name may suggest, in tactile feedback.

HyveOS/Hyve The underlying framework onto which sensors and interactions are placed.

Server Computer used as a central hub in the Hyve network, acting as a controller or to process information when more complex calculations are to be performed.

Satellite Computers used as a medium between the server (controller) and sensors (e.g.: cameras, microphones, thermometers). They provide real-time data which can be read, and then interpreted.

2 Introduction

Sustainability comes in many forms, some easier than others. In most instances, people want to be sustainable, they just also don't want to be inconvenienced. It is the automation team's goal to provide sustainability in a feasible fashion by providing it "cloaked" in convenience through HyveOS.

HyveOS is a software that implements a platform to receive and send data from a house. Data is collected by cameras and microphones placed in public rooms, to which the occupants can issue commands, and received through already owned phones or speakers in the house.

The primary goals for HyveOS are:

Safety making houses capable of detecting dangers such as a burglary or an occupant falling down and not getting back up

Cooperativity allowing houses to balance each other's energy loads and resources

Sustainability letting neighbours to connect with each other and share their own resources, such as tools and food, more easily (and with encouragement from their houses)

Hands-Free Operation enabling people to connect fluidly to the world of data around them through motion tracking systems more accurate than Microsoft's Kinect

Community gently encouraging neighbours to make connections and share with each other

The way this is accomplished is through the network in Figure 1.

2.1 Decisions Made

The decisions described in Table ?? have already been made to differing degrees of certainty.

2.2 Requested Feedback

In our case most of the technological decisions have been fairly firmly made. We were able to do this through extensive research and with the knowledge that what we do can be done fairly independently of the other Solar Decathlon teams.

What feedback we do request is where you see automation fitting in with your part of the house. Also I would like to know whether or not you think HyveOS should increase or decrease the scope of its goals or if you think our goals are misguided.

3 Background

3.1 The Internet of Things and Ubiquitous Computing

The internet of things is the concept that everything has a unique identification code and can interact with the world around it. These interactions range from near field communication, barcodes, or ethernet connections.

The whatis page provides the following excellent summary:

> A thing, in the Internet of Things, can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low – or any other natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network. So far, the Internet of Things has been most closely associated with machine-to-machine (M2M) communication in manufacturing and power, oil and gas utilities. Products built with M2M communication capabilities are often referred to as being smart. (See: smart label, smart meter, smart grid sensor)

The beauty of the concept is best described by its creator, Kevin Asthon:

> Today computers – and, therefore, the Internet – are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is 1,024 terabytes) of data available on the Internet were first captured and created by human beings by typing, pressing a record button, taking a digital picture or scanning a bar code.
>
> The problem is, people have limited time, attention and accuracy – all of which means they are not very good at capturing data about things in the real world. If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling and whether they were fresh or past their best.

Ubiquitous computing is a closely related concept:

> Pervasive computing (also called ubiquitous computing) is the growing trend towards embedding microprocessors in everyday objects so they can communicate information. The words pervasive and ubiquitous mean "existing everywhere." Pervasive computing devices are completely connected and constantly available.

Computing is already ubiquitous and taken for granted, that is simply a truth in our modern life. You probably have no idea how many embedded processors and computing devices there are in the world around you. Together, these concepts raise some major social issues, the tenderest these days being privacy.

Are you willing to risk your privacy in return for protection? You already do in hundreds of ways, it just depends on where you draw the line. I, Calem, am very happy to sacrifice

3.2 The DIY Hardware Movements

4 Research

4.1 Hardware

Most of hardware concern comes down to Arduino vs Raspberry Pi vs TI Launchpad vs Beaglebone, some of

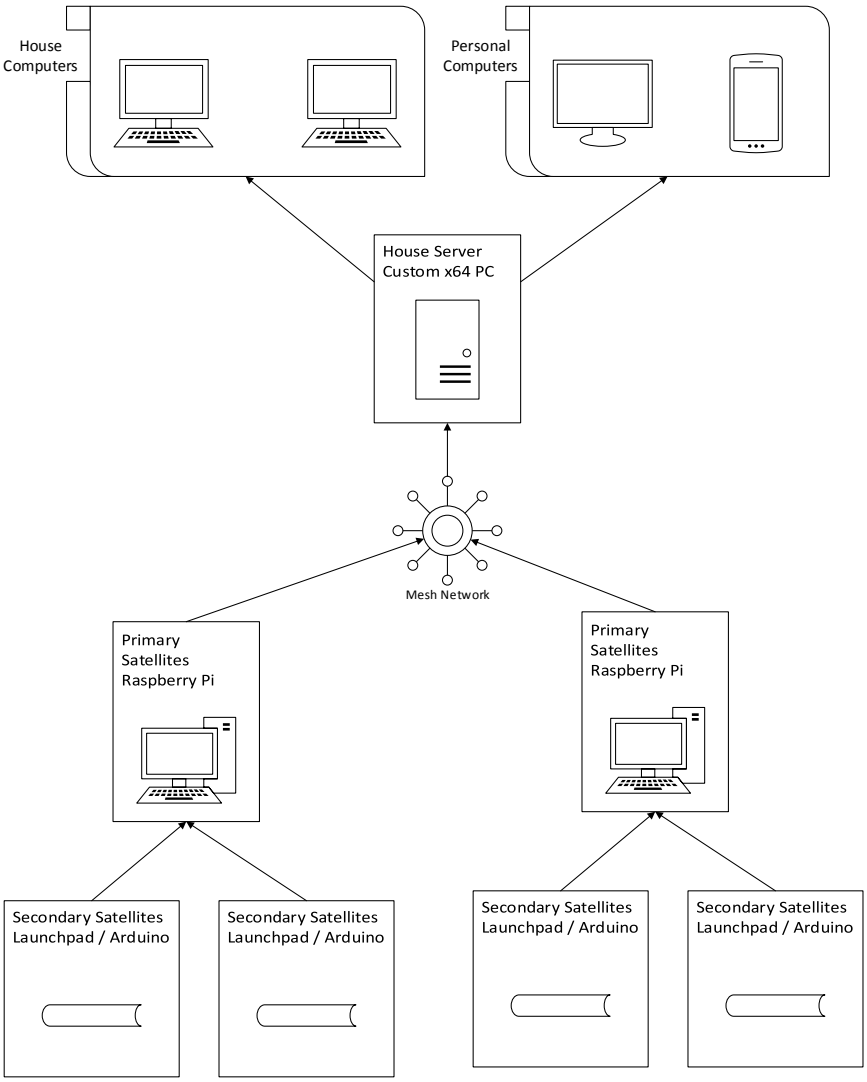


Figure 1: *A description of the hierarchical network employed by HyveOS.*

Aspect	Decision	Firmness (0-5)
Satellites Hardware	Raspberry Pi	5
Server Hardware	Custom PC Rig	4
Automation Satellites	Arduino	2
Satellite Operating System	Ubuntu Server	4
Satellite Peripherals	Audio, Visual	2
Primary Interface	Website (with mobile)	4
Primary Language	NodeJS	4
Analytical Language	Python	4

Table 1: *A tabular description of some of the decisions already made.*

which are depicted in Figure 2. For now, TI Launchpad and Beaglebone will be discounted, though the TI Launchpad is perhaps interesting in that it has the backing of a very large company and is desperate to gain market share.

This distinction is more made at what Hyvdev aims to do. The following quote from James Bruce clarifies the intended purposes of each of these machines.

> The Arduino runs the Arduino firmware, a basic bit of core software which allows it to communicate with a computer over USB and gives access to all the features. You generally wouldn't replace this firmware, but it is possible. Once your application has been loaded, you can just plug it in anywhere and it'll start working immediately, you don't need to reboot, plug in a keyboard, or choose an application to run. It does the one job it's been programmed to do, and it does it immediately.
>
> The Raspberry Pi on the other is a complete, functional, mini-computer. It requires an operating system - the first thing you need to choose that will dramatically affect your experience - and has all the bits and pieces you might expect a full computer to have (just in a smaller scale). Storage is provided from a micro-SD card, while built-in Ethernet allows for networking (you can get networking on Arduino too, but it requires an add-on "shield").

If the Arduino is chosen, then the team chooses its focus is more on typical home automation, such as controlling windows and doors and doing basic home monitoring; alternatively, the Raspberry Pi signifies a much more involved automation process.

The Raspberry Pi was chosen to empower the team to provide a full automation experience, attempting to make the "smart home." As it turns out, a few other groups are also attempting to make the smart home, Nest not the least of them. It is thus our job to also distinguish ourselves from these competitors.

But really, why choose? We can use both, using the Arduino (or TI Launchpad) to control much of the typical home automation and the Raspberry Pi for controlling satellites.

4.1.1 Arduino

The Arduino is a single-board microcontroller that is generally described as perfect for electronics projects. The board has exposed I/O pins for use by other circuits or sensors. A simple example of input and output control that the Arduino can do is translating input from a sensor, such as key presses, to outputs, such as a musical note as long as the keyboard and speakers are attached. Arduino can be programmed from a regular computer, connected via a USB port, which acts also a power source.

Some of the main advantages of using Arduino is both its hardware and software are open source and the Arduino software runs on Windows, Mac and Linux, so it can be programmed from almost any operating system. The Arduino community is actively developing and adding to the programming libraries. It is generally considered most suitable for rapid prototyping in research applications, not for industrial scale usage [1].

The simpler programming environment of Arduino can be seen both as an advantage and disadvantage. It is a lower barrier of entry for non-electrical engineers to program but it does this by adding one layer of abstraction on top of C, which means you don't have control over every bit and byte of the less abstracted controllers. It is also impossible to fully customize the board as it doesn't not allow one to hand-solder components (which at this level, we shouldn't even be considering) Using the Arduino language decreases the portability of the code (not the hardware), so you'd be stuck with Arduino hardware.

Overall, the Arduino board is very flexible with low barrier of entry for those just getting in to hardware hacking and lots of examples online. Though it'd be good to keep in mind that Arduinos are good for small projects and prototyping (i.e. trying things out and experimenting). As the teams advances and becoming more familiar with microcontrollers and requiring specialized function, the Arduino may not be suitable.

4.1.2 Raspberry Pi

Unlike the Arduino, the Raspberry Pi can be and is a full mini-computer. It requires and operating system (such as linux) and with an built-in Ethernet port, the Raspberry Pi can be networked without any additional hardware. The Raspberry Pi has a CPU, memory and graphics processor with full 1080p HD outputs via HDMI port.

The Raspberry Pi can do everything an Arduino can,

[1] On a slightly subjective note, while some seem to thin the Arduino inappropriate for industrial use, it is not because the Arduino is incapable in any way. This is because the Arduino lacks some certifications and does not have an industry certified training program for its use, so one cannot find engineers "qualified" to use an Arduino. Basically, there is no company supporting it from behind supporting the ecosystem of closed systems where everyone gets a piece of the pie, and because managers and human resources are frequently cowards who would prefer their company passes on blame whenever possible to other companies for hardware failures. The "Programmable logic controller" has this market largely under wrap, with a few other big companies dominating the field. It's a wasteful, cowardly, ridiculous situation, but it is what people will do to successfully dilute blame. For a company to use the Arduino, they would have to accept full responsibility for any hardware issues and would also take it upon themselves to ensure they can find engineers who know how to work with the platform, a list that is apparently too frightening for large companies to bother with so they instead endure the steep costs of deeply entrenched solutions. *Calem*

but for many of the electronics projects, Raspberry Pis can be a bit of overkill and makes things more complicated than it needs to be. Though Arduino and Raspberry Pi serve different needs, it is not necessary to choose either or. Arduino and Raspberry Pi can work together since the Arduino can be plugged in and programmed from the Pi.

One main reason we would use Pi over Arduino is the capturing and processing of visual information, which the Arduino simply cannot process. As of now, it may be safe to say the Raspberry Pi is the best microprocessor (single board mini-computer) for multimedia processing. A possible downside to Raspberry Pi is that unlike the Arduino, it is based off of a proprietary processor platform. Certain information about the internal structure of the processor or how the components were put together may not be accessible to the average user.

4.2 Load Balancing

4.2.1 Specification

HyveOS will control and monitor the house's power usage using custom "appliance boxes." Appliance boxes will have appliances plug into them and will themselves plug into outlets. Each box will output a signal representing how much power the device is drawing, and would take as input a binary signal telling the box to allow the device to draw power (1) or to kill power to the device (0). If the appliances as a whole are drawing more power than the house is allowed (e.g. device A draws 100 Watts, device B draws 100 Watts, but the house can only use 150 Watts for whatever reason), the controller will kill some of the devices and only reactivate them when the total usage drops below a certain threshold. The "boxes" in practice might be built into our house's outlets.

4.2.2 Implementation

The house's main controllers (Raspberry Pis) will need to run threads that can manage the signals to and from the appliance boxes. The signals themselves will need either a wired or wireless communication channel. A wired channel will need wiring to connect to the main controllers' general-purpose I/O (GPIO) pins and possibly circuitry for signal refreshing and electromagnetic shielding. A wireless channel will require wireless transceivers for each appliance box. For ease of prototyping, we will use the Spark Core to receive controller input and transmit power usage output wirelessly, and we will use an open-source relay shield for the Spark Core to switch the appliance's "hot" wire (the wire which carries AC power supply voltage) from ground (if the device ought not draw power) or the box's hot wire.

4.3 Software

It is in the software that Hyve is distinguishable. First, let's look at the competitors.

Nest is a home automation company that designs and manufactures sensor-driven, Wi-Fi-enabled, self-learning, programmable thermostats and smoke detectors.

Insteon is a home automation networking technology that enables light switches, lights, thermostats, motion sensors, and other devices to interoperate through power lines, radio frequency (RF) communications, or both.

Pointgrab aims to control all household appliances with natural guestures. Pretty damn cool, but not exactly competing with us yet.

Revolv $299 device that connects existing smart devices, unifying them to make a full smart home.

Nest gets a lot of hype, but is underwhelming from a home automation perspective. It is likely that they will make an aggressive shift into home automation since their purchase by Google.

There are some other competitors, but most follow this tune. It is thus not difficult to see where Hyve can differ.

These other approaches are largely cautious, timid, and realistic. Hyve is a student group, part of the Solar Decathlon competition. We do not need to be realistic at first. We do not need to be cautious. Fortunately, it is the sign of many great adventures (and successful companies) to not be overly concerned about what is considered normal today and instead be prepared for what is normal in the future.

This brings us to Hyve's primary endeavour, which is behaviour modification and true integration of technology and home life, but this topic is saved for the conclusion.

4.4 Available Software

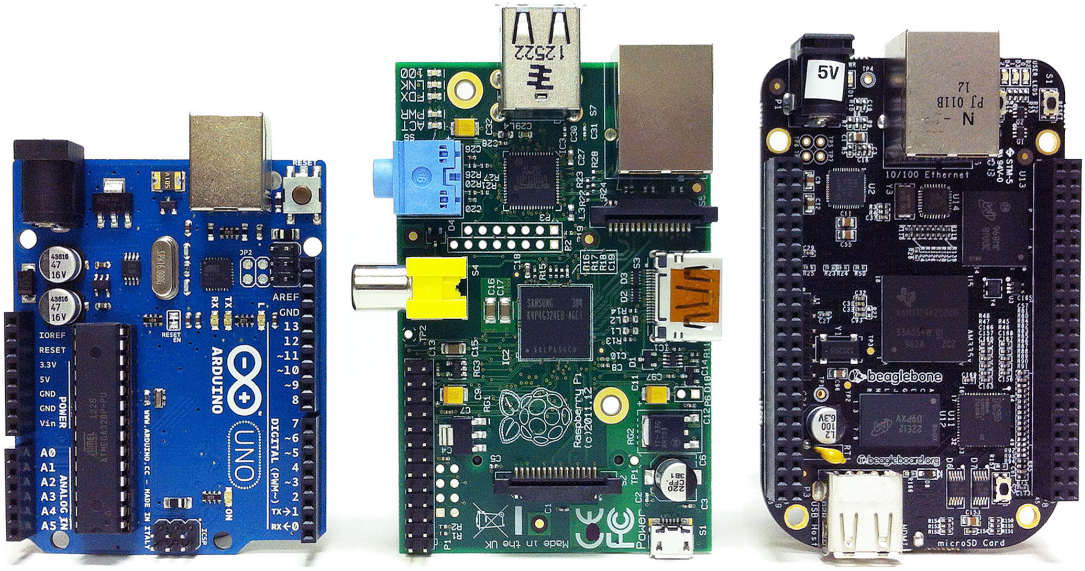
This is the most important section of the paper! Here is what's already out there. More importantly, this is what is available to use.

4.4.1 WiTrack: Through-wall 3D Tracking Using Body Radio Reflections

A technology from CSAIL at MIT.

> WiTrack is a device that tracks the 3D motion of a user from the radio signals reflected off her body. It works even if the person is occluded from the WiTrack device or in a different room. WiTrack does not require the user to carry any wireless device, yet its accuracy exceeds current RF localization systems,

Figure 2: *An Arduino, Raspberry Pi, and Beaglebone from left to right, demonstrating their relative size. Their absolute size should be inferred by the size of their ports.*



which require the user to hold a transceiver. It transmits wireless signals whose power is 100 times smaller than Wi-Fi and 1000 times smaller than cellphone transmissions.

WiTrack localizes the center of a human body to within 10 to 13 cm in the x and y dimensions (about the size of an adult hand), and 21 cm in the z dimension. It also provides coarse tracking of body parts, identifying the direction of a pointing hand with a median of 11.2 degrees. It can also detect falls with 96.9% accuracy. WiTrack can be incorporated into consumer electronics and has a wide set of applications.

The paper for the technology is available here.

4.4.2 Wit Speech

Wit speech is one of several online APIs for voice recognition. It's a very attractive package, though perhaps not as good as Nuance's offerings yet. In any case, they provide an excellent description of their service:

> Wit.AI enables developers to add a natural language interface to their app or device in minutes. It's faster and more accurate than Siri, and requires no upfront investment, expertise, or training dataset.

It's very simple, really, and very powerful since their AI is constantly improving with hundreds of users.

4.4.3 Jasper: Control Anything with Your Voice, Connected to Raspberry-Pi

Jasper is an existing open source platform for developing fully voice controlled applications. Fortunately, it is already designed for the Raspberry Pi, and it is supposed to be very easy to set up on a single Raspberry Pi.

4.4.4 SpaceBrew

This is part technology and part resource.

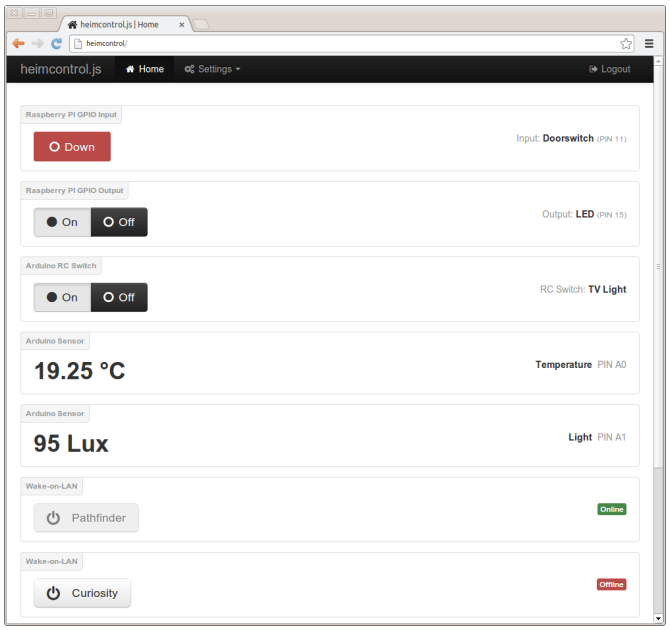
> Spacebrew is an open, dynamically reroutable software toolkit for choreographing interactive spaces. Or, in other words, a simple way to connect interactive things to one another. Every element you hook up to the system is identified as either a subscriber (reading data in) or a publisher (pushing data out). Data is in one of three standardized formats: a boolean (true/false), a number range (0-1023) or a string (text). Once these elements are set up, you can use a web based visual switchboard to connect or disconnect publishers and subscribers to each other.

4.4.5 HeimControlJS

An existing Home Automation suite with Raspberry Pi and Arduino with a control interface. Hell, it's so much like what we planned on doing it could practically be the result.

I'm seriously considering HyveOS being an expansion on this project and then using the extra time we save to rewrite the entire codebase once with the experience we gain from the first write.

This only covers home automation, and does not include more advanced features of HyveOS.



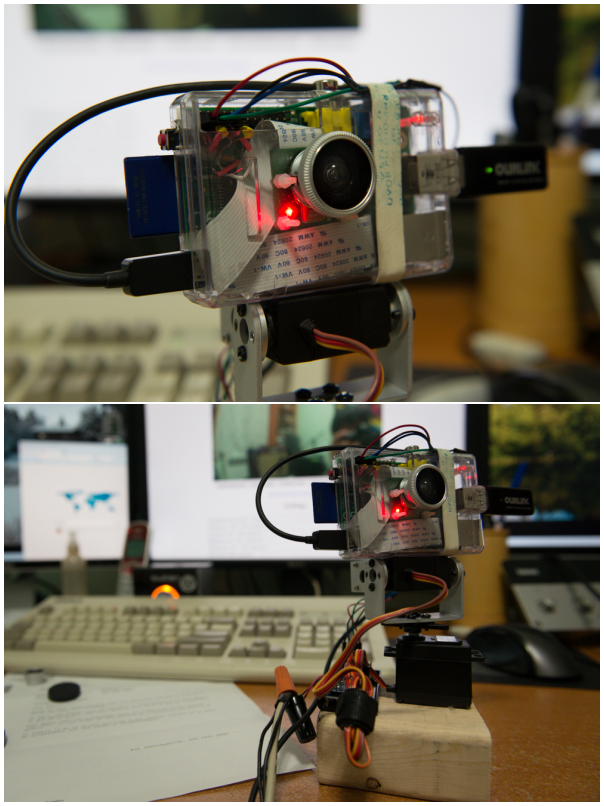
4.4.6 Quake

Not really a resource but you can play Quake on a Raspberry Pi. Damned cool.

4.4.7 RPi Cam Web Interface

This program allows you to stream a live feed from the RPi Camera module(or USB webcam) to a webpage (hosted by the Pi) at a respectable FPS (around 15) . The feed can be accessed by any web browser. The program also allows high-defintion video recording, motion dectection and image capturing. This program can be used for home surveillance purposes. There is currently a prototype built complete with web controlled servos which allows for tilt and pan movements.

Figure 3: *RPi Camera Web Interface Prototype.*



5 Partners in the Corporate World

5.1 Sensor Stacks

Sensor Stacks is a joint Equipmind and Sensorica initiative to make plug and play sensors with cloud data analysis. Preferably offline analysis would also be available, perhaps with a Node-Webkit App packaged with Python scripts and an interface to the data for easy access via programming languages for advanced analysis.

5.1.1 Sensor Stacks Hardware

Hardware is at this point still a little unclear, but the basic hardware that may be used includes a Raspberry Pi, a set of XBee Pro 60mW Wire Antennas, and Arduino's.

5.1.2 Sensor Stacks Software

The part of the project which for now pertains more to me includes the software stack behind the hardware.

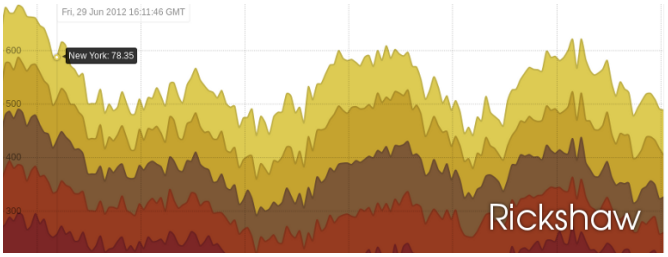
The first important aspect of the software is the primary stack. The database software for this project is TempoDB, a Time Series Database. The following is pulled from the TempoDB website.

> TempoDB offers a ReST API to create new series, and read and write data. Every series can be identified by a system generated id or an optional user specified key.
>
> The data model for TempoDB is centered around the concept of a Series. A Series is a sequence of timestamp/value pairs. This sequence of timestamp/value pairs are measurements for a single source of data. For example, a temperature sensor measuring the temperature in a room is modeled by a single Series. A thermostat that measures temperature, humidity, and barometric pressure is modeled by three Series.
>
> Metadata attached to the Series is used to relate them. Series can accept a name, a list of tags, and a dictionary of attributes. The name is used to present a human readable display name. The list of tags are used to tag types for the Series. The dictionary allows key/value pairs to be attached to the Series.

Altogether TempoDB seems to be a very convenient method by which to contain data for sensor stacks, all of which will be time dependent. One major concern is that TempoDB is neither open source nor free. Indeed, it is relegated to being an online service, making local analysis and storage impossible. While this database solution may be untenable for a final solution, it will make for an excellent prototyping solution.

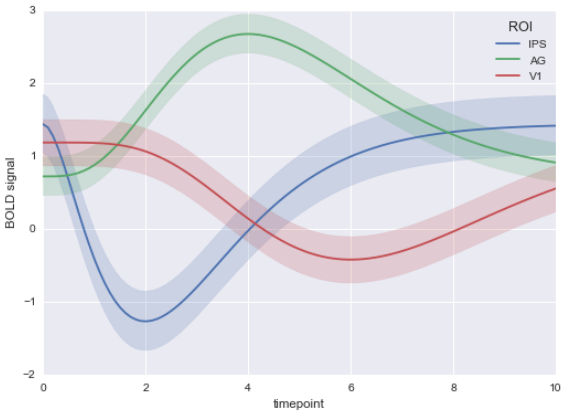
The next major part of Sensor Stack's software is the framework. Node.js is a platform built on Chrome's JavaScript runtime for easily building fast, scalable network applications. It "uses an event-driven, non-blocking I/O model that makes it lightweight and efficient, perfect for data-intensive real-time applications that run across distributed devices." Node.js also has Node-Webkit, which allows for the easy deployment of "native" apps to Windows, Linux, Android, iOS, Macintosh, and Windows Phone.

The GUI for the program, being primarily a webapp, will be HTML, CSS, and JavaScript. The more interesting aspect of software is the plotting. The current plotting software of choice is considered to be Rickshaw.js, which is specialised to plotting time series data like the following:



While Rickshaw is excellent for plotting time series data, it does not seem well suited to heavier analysis, so another solution may be required, which could be used to visualise "pro" features, such as machine learning and more advanced statistical analysis.

A more appropriate plotting library for advanced analysis may be seaborn, which produces significantly more elegant and descriptive plots that can be displayed as pdf, svg, png, etc. like the following:



6 Strategy

6.1 Behaviour Modification and Working Toward a Better Society

Just having the technology to be greener isn't sufficient, as proven daily across the globe. Apparently it isn't even sufficient for the greener, smarter technology to be cheaper.

It is possible that the reason for this isn't so much that people don't care but because these technologies are not made convenient or are blocked by established companies.

7 Cost Analysis

7.1 Raspberry Pi Satellites

Each Raspberry Pi Satellite is approximately 100 dollars with a minimal configuration and a camera.

7.2 Server

The server would cost approximately 800 dollars.

7.3 Arduino Automation

Arduino automation cost is thusfar unknown but projected to be under 100 dollars per satellite.

7.4 Load Balancing

The following has been assembled as a bill of materials for load balancing.

39.00	1 Spark Core Wireless transceiver/microprocessor
29.70	3 Spark relay/power monitor shields
04.00	jumper wires

8 Conclusion

Hyve's primary endeavour is behaviour modification and a bolder marriage of technology and the home. It is through true integration of and comfort with technology that communities can become closer together.

Hyve is designed to protect the individual, his property, his person, and his privacy, and also to help connect him to his neighbours. While I expand this paper, this will be further detailed.