CSE 181A - Senior Design

Sparky Strip
A Project Plan

By Pink Squids

Date: November 30th 2015

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Response to Mentor Comments:

The following is a list of necessary changes to optimize the efficacy of our report.

- Executive summary re-written (post response to comments).
- Gave more attention in addressing potential market (section 1.1).
- Compare and contrast bullet points added against competing products (section 2.2).
- Requirements expanded upon (section 3.1).
- Objectives expanded and elaborated upon (section 3.3).
- Subsystems expanded upon (section 4.2).
- Specific tasks added (section 5.2).
- Milestone gantt chart inserted inside of document (section 5.4).
- Specific itemized list created for resources (section 5.5).
- References reworked (post section 5.5).

Executive Summary (5 points)

Knowledge is power, and yet many homeowners have no clue where their megawatts are going each month. Project Sparky Strip provides homeowners with a way to find exactly what their many devices are doing and how much power each uses. With this knowledge the homeowner is armed with the tools needed to make smart power decisions. The best part is that Sparky Strip works without any interaction by the user - simply replace a existing power strip, configure the wifi, and it is good to go!

Sparky Strip works just as any other power strip, only with Sparky Strip the homeowner can view both live and historical information about what devices are plugged in and how much power each device is using. Sparky Strip can do this by producing unique signatures of each plugged-in device by using signal processing methods. These signatures are then transmitted to the cloud where a machine learning model is used to identify the individual devices and the power usage of each. All this information is stored in a database where our web application is able to access the information and neatly display it to the user.

Awareness is the first step and with Sparky Strip the homeowners can raise awareness about their electricity consumption and make positive changes towards energy conservation. Beyond the individual household, our database will become a treasure trove offering unique insight into the households of America. This data may even offer insights to help direct government policy. The potential is unlimited.

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Chapter 1. Introduction (15 points)

Let us use the following pages to describe to you how and why we all need to monitor home power consumption. Not only is this a push for the greater good of humanity, but also a highly needed and valuable product for homeowners everywhere as no one really knows where their power consumption is going. There are devices to assist the homeowner in that regard, but it takes a log of manual work and data logging to even figure out what one appliance is doing, let alone the whole house. What If we could monitor power use and gather appliance information without programming or really any work at all? And what if all this historical information was available at the tips of our fingers on a phone or tablet? This is the inspiration behind the Sparky Strip. Let’s get a bit more technical.

The more information we can gather the more power we will have. In the case of smart homes we are concerned with just that, power. The problem is that devices often consume much more power than necessary, devices may not be working as desired, and with smart power we can control the management of power consumption through this embedded device, the sparky strip. In addition to the previous remedies that will be found when creating this device we will help with the sage of load signature analysis for wireless control and monitoring, identify unique signatures through the waveforms of each appliance during operation (unique voltage, current, power), and sample waveforms to identify start, run, stop states of each signature.

1.1 Motivation (5 points)

Currently there is very little real data of device usage patterns. Power companies, governments, and consumers have little idea where power is being consumed. Awareness is the first step to changing usage patterns yet today little is known more than the megawatts used every month. What if there was a device that with no work on the user's part identified who, what, and where power is being consumed? This is the problem we are solving, and the potential impact is huge.

Potentially the market is huge with government standardization and elevation of home quality. When this product become a regulatory product to ensure home safety one can assume that it will be a multi-million user system of users living in safer environments. Although, without being too grandiose initially this product will be marketed to newly manufactured homes as a safety standard.

1.2 Potential Impact of Work (10 points)

1.2.1 Relation to EE, CpE, and CSE (2 points)

As we are all computer science and engineering majors, the relevance to our major is greatly represented by the project as the necessary skills for this project require aspects of our courses we have taken such as digital signal processing circuit design, and an understanding of databases and network protocol. In terms of the potential impact of our work. This is dependent on the accuracy of our device in being able to deliver the proper return of the appliances inserted into the device and being able to understand the data that is being transmitted through the device to be able to detect the appliance. The possibilities posed here with a success would result in being able to power manage and detect areas where power consumption is greatest to allow consumers and providers of electricity to manage power better which would be a major impact that would be due to the results of our work.

1.2.2 Global Context (2 points)

In consideration of a global context, the device has the potential of assisting users with their power consumption to better understand what devices are pulling the most power. This will be especially useful for users in locations where the power management is not very well maintained in order to conserve on electricity. This in term has a major impact in a global context as conservation of energy is greatly needed.

1.2.3 Economic Context (2 points)

The impact of the work on society will be very world altering as it is both an environmentally focused device and an economically profound concept. As well, a potential impact on a global context, the maintaining of power could lead to major reductions in electrical costs for communities as people will be able to control their costs of power by being able to reduce it through a monitor of their appliances plugged into the device. This is very important and is needed in the market as the world today is very much dependent on electrical appliances.

1.2.4 Environmental Context (2 points)

In order to create a device such as this, a consideration of the potential environmental impact does come into play. In this case, it would be lowering the carbon footprint that people place on the Earth as it would result in a better control of power and this leads to less waste of electricity of the users of the device as power management is taken into consideration.

1.2.5 Societal Context (2 points)

Our project can make an impact on society through awareness of energy consumption. This will change the way people view electricity as well as electrical devices. People will be able to visually and grasp an idea of how much energy individual devices use and how that affects our world and environment. Through this project, society can find awareness. Through awareness, real change can be made towards a better, cleaner, healthier world.

Chapter 2. Background and Related Work (10 points)

2.1 Background (5 points)

The device in and of itself is fairly intuitive to the end user, but to actually understand the ins and outs of the device you must have fairly intimate knowledge of embedded devices, algorithms, applications, and servers. In addition, to be able to present the project in a consumable way one would need to know about topics closer to web development. Beyond these requirements to understand the device one must have knowledge of signal processing, machine learning, and data manipulation.

2.2 Related Work (5 point)

While there are competitors on the market we strongly believe that our solution is the best and most profound application and use of such a device. Since the project both includes a large breadth and depth of quality and capabilities we aren’t concerned about devices that are perceived as competitors, such as a smart home lighting switch.

Since we will be constantly giving feedback and control to the end users our device will reign for superior to other. Panasonic has already tried to come to market with a product for the home that claims to be a, "smart home power monitor." This product is a home add-on and boasts the affordable price of 38$. The product can be seen here: http://shop.panasonic.com. This device isn't aiming for the capabilities that we are though. This device first off is only an add-on. It only offers power control on and off and socket control from a tablet. What we plan on providing is a much more robust concept. We are looking at device signatures and providing real time feedback to end users that monitor power consumption. Although Panasonic is potential in our space we don't feel that their product is threatening nor makes our product obsolete, in fact, we would be inspired by Panasonic wanting to one day work in partnership with us to fully develop our extremely practical and useful device.

Compare contrast with panasonic are the following:

1. Sparky Strip will provide a UX similar to Panasonic Smart smart home’s UX 2.
2. Sparky Strip will be embedded behind a socket unlike Panasonic's product which goes over wall sockets.
3. Sparky Stip will communicate all through one centralized device. Panasonic uses many different components to make the system work.
4. Sparky Strip will gather application signatures and Panasonic does not.
5. Sparky Strip and Panasonic Smart Home both have power consumption control.

Chapter 3. Problem Statement (15 points)

3.1 Requirements (8 points)

The device should be portable, lightweight, and easy to use. The device will be boxy. This box shape will be an innate feature of our product because it is confined by an Arduino, oscillator, and additional I/O devices to read electrical signals. When taken to market the device will need to have a waterproof encasing, but for the purpose of this course we will not be concerned with waterproofness. Our device will have a wireless component because it will need to send off information to a database. The frequency and amplitude ranges that will be taken into account will be wide and varying as we will need to be able to discern values from various wall inputs. The project will be difficult and hard to structure for efficient data gathering and manipulation. Linear/polynomial regressions (best fit lines) will be one way of implementing machine learning to find clusters of data which will associate as a device's signature. This is the metaphorical tip of the "iceberg" of what and how we can use machine learning on this project. Further, we will need to properly organize our data by setting up a server, database, and hopefully an interface in which end users can get a visual representation of the work, device's signatures, and monitor power usage.

3.2 Constraints (4 points)

As we move closer to our deadlines our biggest constraint is having time to fully develop and build out our project to meet the specifications and standards in which we have set for ourselves.

Another constraint we have is finding the most compatible system to produce the outcomes in which we desire. This may include power consumption concerns, latency between the Arduino and the servers, and relaying accurate data to the databases. We will search for a device the has a feature set that is as close to what we need to be as minimalistic as possible.

As far as additional constraints, since we have already worked out a prototype, much of the roadblocks in core functionality have already been figured out and are working today.

3.3 Objectives (3 points)

We aim to help the end user, whom is a home owner or smart home dweller. Our device will provide a platform for users to have smart power. This is the ability to identify the consumer's usage of electricity to provide higher efficiency in both the utilities provisions from the providers and the energy consumption of the consumers.

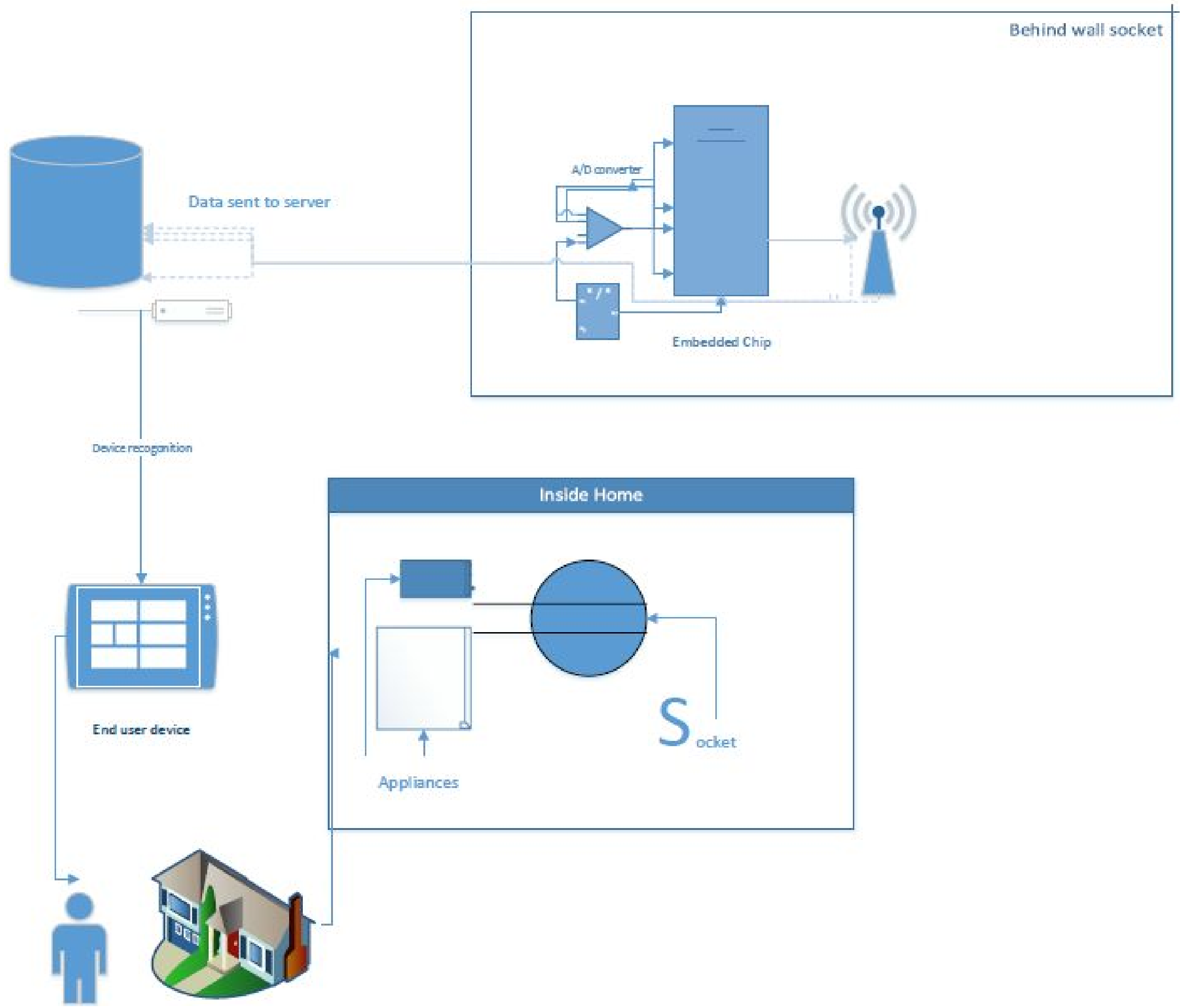
By helping the end user we are helping society as whole. This is our main objective which is to create a safer more environmentally conscious world. By monitoring power consumption and creating extra checks upon this power we are helping monitor control and regulate the already messy power grid.

We strive to both have a economic impact by saving end users money by preventing tragedies of home fires and also we strive to impact the world in which we live by making the world a power consumption safer place.

Further, we believe with proper understanding and implementation we can make end users satisfied with their power consumption and empowerment we give them by using sparky strip. We hope that this will motivate users to think green and help reduce humanity's footprint on the earth.

Chapter 4. Technical Approach (20 points)

4.1 System Block Diagram (5 points)



4.2 Subsystems (5 points)

At the highest level we have a home. Going a level deeper we have appliances attached to a wall sock, behind the socket is a CPU and devices to read signals. That information is submitted to an offsite server and the information is understood and received by the end user.

The first subsystem is the embedded devices. This is composed of a arduino and a ac/dc reader. Here we will gather samples and look for meaningful data.

At the 2nd level we send our data points off to servers where they determine the device's signature. Here we run complex algorithms to determine if the device matches the device's signature.

At the 3rd level we feed the information from the servers to the end users. Here we display power usage and tell the user the type of device that is plugged in.

4.3 Interfaces (5 points)

Notice that there are different types of arrows drawn on the top down diagram. The dotted arrows represent wireless signals. The solid lines represent the chain of action in which the data path follows. We will be using HTTP and a custom protocol on top of the TCP.

Describe the interfaces between subsystems and with the environment.

4.4 Technology Options (5 points)

We are using very fundamental components for this project such a component for phase and frequency, a component to recognize current, a 32-bit CPU to gather samples, a wireless transmitter to send the data out, and a server.

The end user will also need a device such as a personal CPU, an iPad, or a smartphone.

In terms of software, we will be using legacy code as well as refining the code and writing new code to add new features. Code will be primarily in C, Python, SQL, and web (HTML, XML, JS)

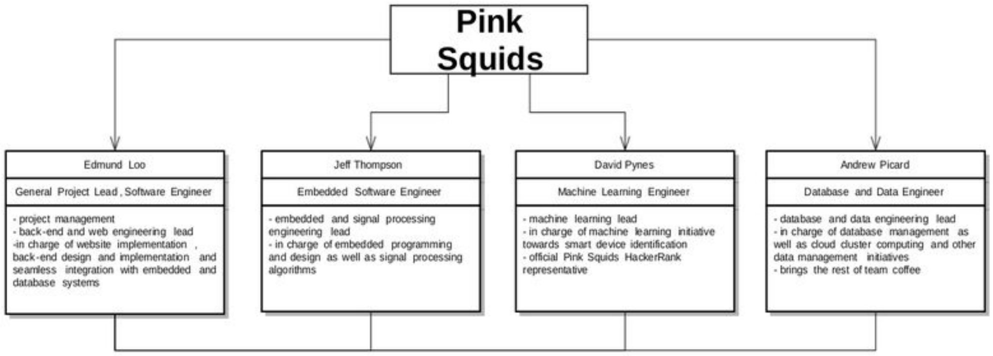
4.3 Initial Choice and Justification

The most promising technology that we are using is the legacy code coupled with machine learning. Since the hardware has already been set up from our team from last year we know that we are able to gather sufficient amounts of data. The most promising next step is what we will be able to do with this data.

The ability to make sense of large data sets makes new efficient algorithms very promising for their suitability.

Chapter 5. Development Plan (25 points)

5.1 Team Organization (5 points)



5.2 Tasks and Responsibilities (5 points)

All members are expected to assist in all areas, but below are the primary areas of responsibility:

Edmund Loo

- Project lead
- Hardware communications
- Back-end and Front-end web development

David Pynes

- Identification algorithm
- Machine learning research and implementation

Jeffrey Thompson

- Physical device build and testing
- Firmware of device to include sampling and signal processing

Andrew Picard

- Data management
- Database administration in the back-end

5.3 Tools (5 points)

We will be using Slack, Trello, and our Facebook group in terms of communicating within the group in order to make sure we work in a timely manner.

In terms of source control, we will be using GitHub to share our work.

We have a PCB Layout already designed for the device. CalPlug also has a soldering station will all needed tools.

C++ will be used on the device starting in the Arduino environment, later switching to Atmel Studio if we have time.

Python will be the main language used on the server. The database type and machine learning algorithms are still being researched.

5.4 Timeline (5 points)

First week or two will be dedicated to bringing our tools together and researching the best tools to use for the project itself (database, web server, connectivity, sample collection, early testing).

Next two weeks will be dedicated to analysis of the problems we have ahead of us. This includes how we will overcome these issues (machine learning issues, sampling issues, clustering issues, hardware issues, etc.) as well as further progressing on the intended goal of the project.

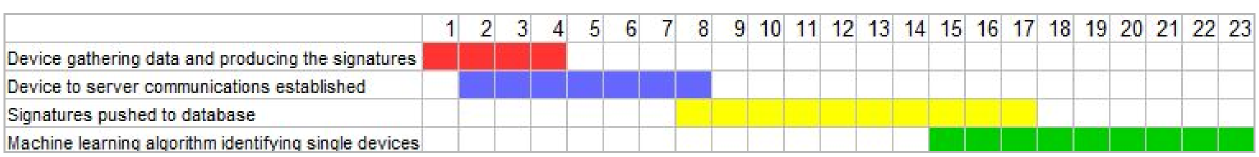
The rest of the weeks will consist of the team implementing the design and testing appliances on the Smart Strip. Collecting samples as well as understanding the data that is being pushed to the web server in order to be able to detect what devices are being plugged into the smart strip.

Near the end of the winter quarter will consist of wrapping up the project and preparing for the presentation (website to present data findings).

Milestones:

- Device gathering data and producing the signatures
- Device to server communications established
- Signatures pushed to database
- Machine learning algorithm identifying single devices
- Results displayed to the user

Gantt Chart:



5.5 Resources (5 points)

In terms of finance, we are expecting no more than a $900 dollar budget. Most of the cost is attributed to the physical aspects of the device with the fabrication of the custom circuit board the largest expense. We are making two prototype devices and but as we are working with high voltage AC we will have spares handy. CalPlug is assisting us and has provided most the resources we will need, this includes all tools such as soldering equipment, Oscilloscopes, and access to a server.

Itemized costs:

- Arduino Due x2 $85
- fabricated circuit board x6 (spares) $415
- components to populate board x3 $120
- custom case x2 $200
- cloud hosted server (4 months) $80
- **Total: $900**

References (5 points)

[1] Faraz Milani, Kelvin Liang, Young Min Kim, Matthew Cai,Arthur Zhang, G.P. Li, "Intelli-Home Electronics Interpreter." - *Senior design 2014.*

[2] Https://www.panasonic.com/uk/consumer/smart-home-learn/smart-home/ -*Panasonic*

[3] https://en.wikipedia.org/wiki/Home_automation -*Wiki*

[4] Jeff Thompson, Edmund Loo. "Associate Researcher Consulting" *- Cal Plug 2014*