CEE186

(Final Report)

ShowerThoughts

Tellefsen Hall Smart Water Monitoring

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Entering yet another year of consecutive drought, Californians know that water conservation is key. However, it is diffcult to understand individual water usage when it flows freely out of the faucet. This project will measure the water usage of the showers in Tellesfen Hall, a dormitory comprised of 44 students at UC Berkeley. The measurements will be used to trigger real time warnings of water usage in the form of a LED visual display in the bathroom stall. A web-based visualization shows residents all of the shower data in both plots and tables. To encourage people to view the website, the shower availability is shown, so that people can check if there are empty stalls from their laptops.

Introduction

The motivation for this project is to encourage a decrease in water use in a communal living environment as well as promote understanding of how much water residents are using on a daily basis. This type of project can be scaled up by having flow meters on each water outlet in a home and provide useful data about how water is being used in the home. Some issues with this type of system are waterproofing the electronic components and achieving reduction in water use only through decision support and no actuation of the flow of water. This project collects data on water usage in showers to show residents their water usage and encourage users to use less water in a time where water is an extremely precious resource.

Relevant literature

Many parts of this project have been attempted before. Equa[1] is the closest project: it calculates flow and outputs it to a screen, optimising consumption through alarms and timed music playlists. Nevertheless, it does not lend itself to scaling easily, and includes no temperature sensor or web visualisation. Because Arduino projects are usually undertaken by people over twenty-one, a popular application of flow meters is a smart keg[2], and it includes web visualisation and temperature control. The last piece is the modularity of the system - the system is distributed and centralised (many wireless-enabled Arduinos talk to one server by transferring each message sequentially to other nodes until the final destination). The ZigBee protocol is perfect for this application[3]. The server itself is a Raspberry Pi, mainly because it is cheap, powerful enough, and can support ZigBee as well, through a serial interface[4]. Data is then sent to Orchestrate[5]. The web interface uses Bootstrap[6] and morris.js[7] in order to display data fetched through Orchestrate's REST API.

Focus of the project

Shower Thoughts's focus is to record shower data and visualize the water usage to the residents of Tellefsen Hall. Through stored data, we can compare past behaviors with current thoughts and strategically decide on allocation of user's shower time.

[1] Link
[2] The Adafruit one is here: Link
[3] Link
[4] https://www.sparkfun.com/products/11812
[5] http://orchestrate.io
[6] http://getbootstrap.com
[7] http://morrisjs.github.io/morris.js/

1 Technical Description

1.1 Bill of Materials

1. Adafruit Liquid Flow Meter - Plastic $\frac{1}{2}$" NPS Threaded Link
2. Raspberry Pi 2 - Model B - ARMv7 with 1G RAM
3. Arduino Uno (Figure 5)
4. Black Plastic Boxes for LED Board and Wire Management (See Figures 2, 3, and 4)
5. 1 LED Board (Figure 2 and 3)
   a) PCB Boards from Fritzing
   b) LEDs and wiring provided by Jacobs Hall
6. 8GB MicroSD Card
7. 2 XBee Radios
8. XBee USB Explorer
9. Wifi Dongle for Raspberry Pi 2
10. Waterproofing Materials (Figure 2–4)
    a) $^1/_8$" Black Irrigation Tubing
    b) White Bathroom Sealant
    c) Acrylic for LED Board Window
11. Orchestrate Software Subscription
12. Github Website Hosting Services (Figures 6–11)

1.2 Hardware

Items 1 through 9 on the Bill of Materials consist of the hardware portion of the project. The summary of the system is the flow data is collected using an Arduino, an LED board flashes with the amount of water used, and the data is then uploaded to the Internet for analysis and visualization. A flow diagram of the project is shown in Figure 1.

A flowmeter was installed in a shower at Tellefsen Hall to measure the flow of water to the showerhead. The flowmeter sends data to an Arduino Uno placed outside of the bathroom to protect the Arduino from water and humidity damage. After processing on the Arduino, data is sent to the LED board mounted on the wall in the shower stall.

The LED board consists of a PCB board manufactured by Fritzing and 4 LEDs. This board shows the gallons of water used while someone is showering by flashing LEDs. Each LED corresponds to 15 gallons of water used, which is about 6 minutes of shower time. The first, green light begins flashing when the shower is turned on, once the 15 gallons have been used, the light stays illuminated and the next light begins to flash. After 60 gallons (24 minutes) have been used, all four lights have been illuminated, so all lights flash on and off until the user ends their shower. Figure 2 and 3 show the flow meter, LED board, and the waterproofing tubing.

Black waterproofed tubing protects the electrical wires connecting the LED board and flowmeter to a wire management box mounted outside the bathroom. This box acts as a break in the waterproofing tubing and was in a preliminary design when an Arduino Mini was used to record data. The wires are then connected to the Arduino Uno from the wire management box which will log the flow meter data and actuate the LED board. The data is then sent wireless on a XBee radio to a Raspberry Pi with a WiFi dongle that will package and upload the data to the Orchestrate database. Figures 4 and 5 show the wire management box and the connected Arduino Uno. Please note that the Xbee radio is not shown in the picture but is part of the intended project design.

2 Programming Outline

2.1 Data acquisition

Once the shower is turned on, the flowmeter begins sending pulses to the Arduino after 2.25 mL travels through the meter. These pulses are recorded by the Arduino code and converted into units of gallons. The Arduino also calcu-

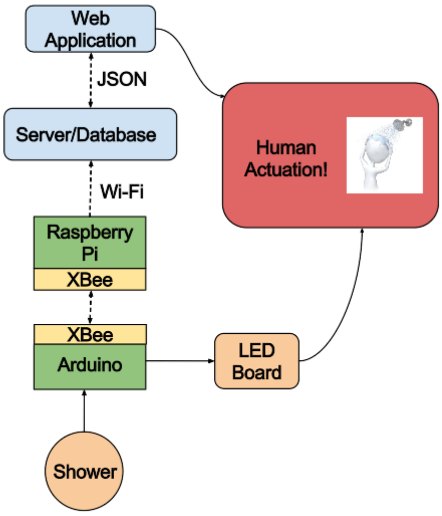


Figure 1: Flow diagram

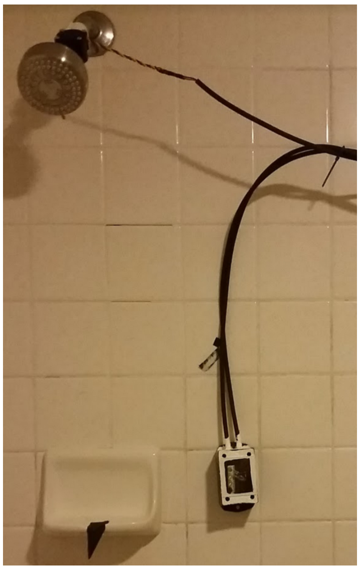


Figure 2: Flowmeter installed on showerhead

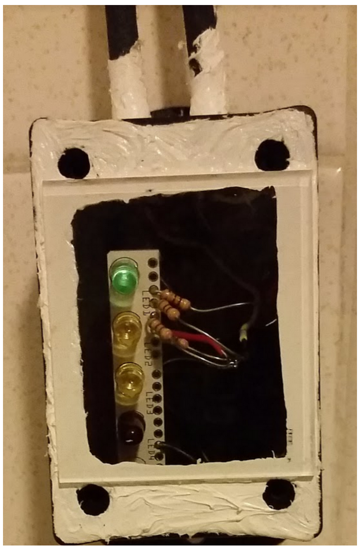


Figure 3: LED board

Figure 4: Wire management box

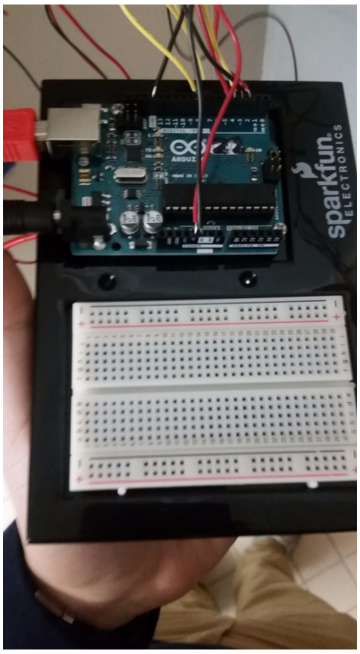


Figure 5: Connected Arduino Uno

lates the amount of time between the pulses, and uses this to calculate the flowrate.

2.2 Connectivity

The communication between the flow meter, the LED Board, and the Arduino is wired. The Arduino uses its TX and RX ports to talk to the XBee. Because XBees work with plain serial buses, the same code used for Arduino to send the data over to the XBee can be used to send data to the Raspberry Pi with a wired serial connection.

The Raspberry Pi then sends its values to Orchestrate over Wi-fi, and backs up the values captured in a text log file that can be recovered in case the Wi-fi doesn't work.

The Web Application then uses Orchestrate's REST interface to query the database, and outputs the result.

2.3 Packets

From the Arduino to the Raspberry Pi, data is serialised. For efficiency purposes, each measurement is written over one line, like so:

$$s; f; a; n$$

Where s is the shower number (1-3), f is the flow in gallons per seconds, a is the total amount of water since the last zero measurement (i.e. when the shower started), and n is a boolean that is true if the measurement sent was preceded by a zero measurement (n, therefore, is true whenever it is the first measurement of a new shower).

The Raspberry Pi then adds the timestamp to the measurement and sends it to Orchestrate through a json POST request. The Web Application, similarly, receives data through a Json GET request.

2.4 Visualization

Through Web-based repository hosting service, Github, (URL: https://ksk5429.github.io/) the data collected is hosted online so that it can be accessed everywhere. This website provides visual representation of shower usage instantaneously and over time in Tellefsen Hall. The first graph displays flow over time, and the second shows total flow, which is an integration of the flow over time. The donut chart illustrates percentage of each shower stall, distinguished by the rank so users can see which shower stall is used most. On the social panel facts about utilization of shower are posted.On live panel, people can reserve shower times in advance. The website was designed with Bootstrap, the responsive developing platform. Technically speaking, the data is fetched through database called Orchestrate, called by Javascript through JSON GET request.

2.5 Actuation

As the flow meter sends data to the Arduino of the gallons and flowrate, this data is sent back to the LED board, which illuminates to notify the user of how many gallons they have used so far and encourage the user to end faster. Thus, there is also an element of human actuation, in presenting the data to influence behavioral change. In addition, the data is visualized on the web application, allowing residents to visit the website and see the amount of water they used during their shower. Statistics are provided alongside the raw data, such as most popular time of day, most popular day of the week, and average shower length. The figure 6 describes the web application.

When a user visits the website, one can figure how long he/she took shower and how much water was used for shower. It is usually shocking to find out that one could use double amount of water by taking 20 minutes shower instead of 10 minutes, which will change one's mind for the next shower. As a matter of fact, above Figure Dashboard homepage shows that one person used twice as much water as the other two users.

Figure 7 and Figure 8 display the collected data on a chart, transferred by JSON to the responsive framework, morris.js, to show users how much water was used. Users of all shower stalls could realize time and amount of the water they used, so that they can better their performance next time.

Social Panel (Figure 9) displays facts about the people's usage of the shower nodes, which were calculated by the data from Arduino sensors that were installed on the site. People could see different facts and realize something real about their water usage, to change the behavior, which we are ultimately hoping for.

In the Live Panel (Figure 10), people can find out which shower is currently being used or not. By displaying this panel, we could track a traffic of the shower stalls and avoid problem that arises with a traffic.

The Statistics Page (Figure 11) displays the data accumulated over the history of all usage. All sensors on all nodes report different data on this table.

In summary, three main parts serve as the core structure of the website. Inside a container of the Dashboard page are header, sidebar, and contents. On sidebar are three main sections: Dashboard, About, and Statistics. Main content displays Water Flow Chart, Total Water Flow Chart, Donut Diagram of percentage of each node, Social Panel, and Live Panel. Water Flow Chart shows instantaneous water flow rate of each node, whereas Total Water Flow Chart integrates, since the start of the shower node to the end, each flow rate data to display the cumulative usage of each node. If there are three nodes, three lines will appear on the same plot, with different colors.

3 Discussion

Our cyber layer functions to talk about utilitarian facts by Cloud Computing (CP), by using programming languages, Python, Javascript, and Html, to program the Real-time data (RTD) collected from sensors of Arduino on three shower nodes. Radio of Xbee of Arduino delivers information immediately to the online server, Orchestrate, and updates cyber layer of a website, designed with a responsive web development, Bootstrap, which allows users view

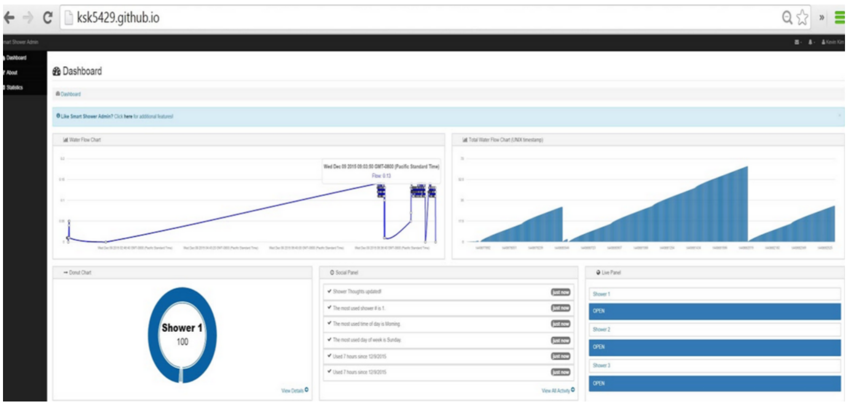


Figure 6: Dashboard homepage

Figure 7: Water flow chart

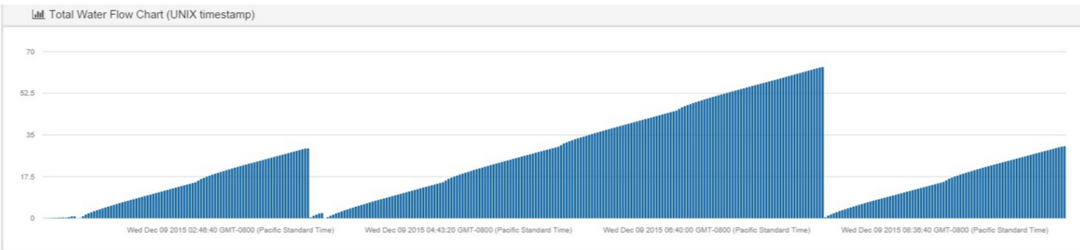


Figure 8: Total water used chart

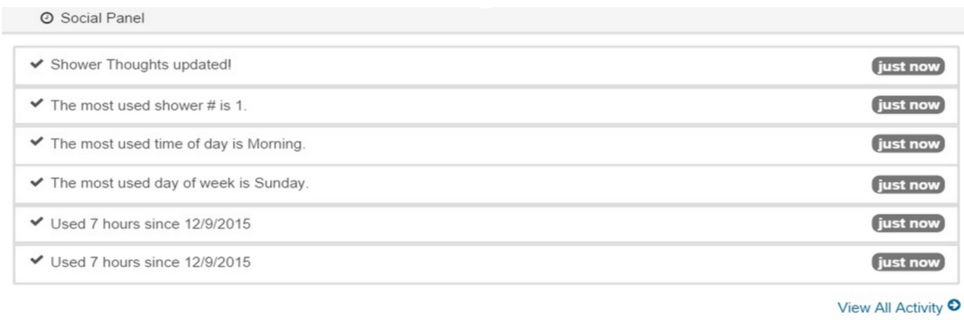
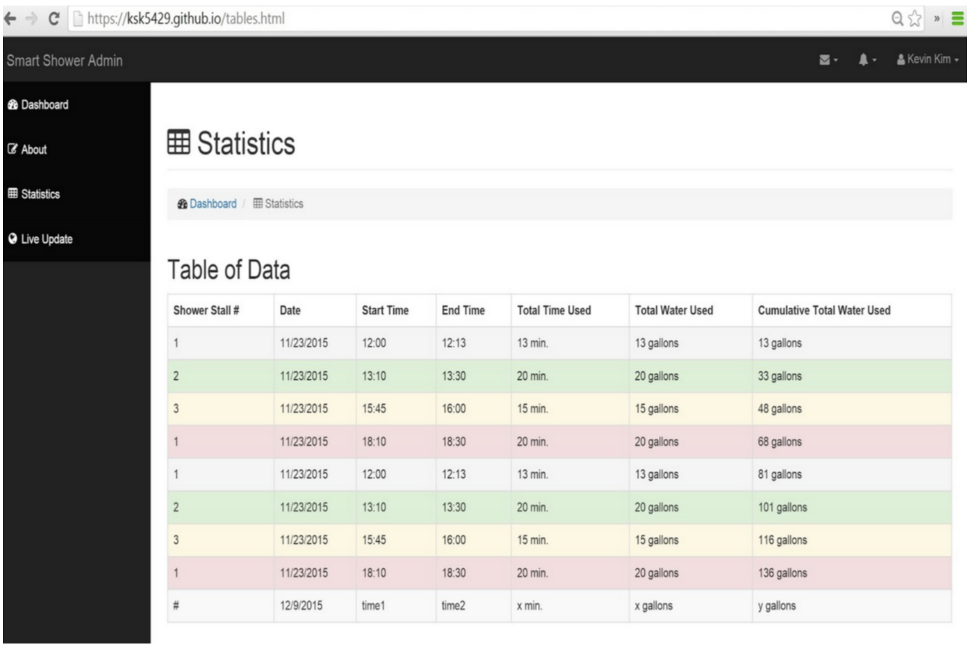


Figure 9: Social Panel

Figure 10: Live Panel



Shower Stall #	Date	Start Time	End Time	Total Time Used	Total Water Used	Cumulative Total Water Used
1	11/23/2015	12:00	12:13	13 min.	13 gallons	13 gallons
2	11/23/2015	13:10	13:30	20 min.	20 gallons	33 gallons
3	11/23/2015	15:45	16:00	15 min.	15 gallons	48 gallons
1	11/23/2015	18:10	18:30	20 min.	20 gallons	68 gallons
1	11/23/2015	12:00	12:13	13 min.	13 gallons	81 gallons
2	11/23/2015	13:10	13:30	20 min.	20 gallons	101 gallons
3	11/23/2015	15:45	16:00	15 min.	15 gallons	116 gallons
1	11/23/2015	18:10	18:30	20 min.	20 gallons	136 gallons
#	12/9/2015	time1	time2	x min.	x gallons	y gallons

Figure 11: Statistics Page

or reserve the time on each shower node, so that shower stalls can be upgraded with smarter cyber systems.

In addition, people like numbers pertaining to the facts about themselves. It increases one's awareness toward daily shower usage and instills a sense of water preservation in their minds. To motivate this effort, administrator posts of total usage are expected to motivate water preservation by utilizing social dynamics to promote one's incentive to minimize water usage. In the big picture, this is an important step in addressing the Global Water Shortage because final outcome of this project will be reduction of overall shower usage. In other words, by allowing one to monitor every drop of water on every shower stall, we could prevent the ones who abuse the privilege of having water flow freely out the tap on daily basis.

Our project motivates further water infrastructure projects. The power of knowing the quantity and time of water used by the showers could further implemented in such a project as a recycled water project for a residence. Capturing greywater from various water sources around the house to water landscaping and flush toilets is important as fresh water becomes scarcer. The water would first need to be tested for contaminants, but it is clear to see that there is potential to reuse much of the water in residential homes. In addition, these flow meters can be installed on other potable water fixtures such as sinks and toilets to further provide data about the relative amounts of each activity in the home, information that a public utility would be interested in.

One motivation was discussed in class but never implemented was modeling the use of natural gas to heat the showers. Reducing water used in showers also reduces the amount of heated water generated by the hot water heater, therefore saving natural gas. Using simple thermodynamic principles, the amount of natural gas used to heat the water can be extrapolated.

Summary

Shower Thoughts accomplished the original goal of measuring shower data and visualizing the results to residents of the house with the ultimate goal of reducing water usage. Residents using the smart shower commented that the mere presence of the flowmeter and LED board made them more aware about how long their shower was and they decided to shorten their shower. Through our implementation of Shower Thoughts, our group came up with new ideas to expand the current setup to include actuating the flow of water such that the flow of water is slowly reduced once a specified amount of gallons is used. Also, using thermodynamics to determine the amount of natural gas used to heat the water used for the shower and visualize the savings with a reduced shower time. With more data, we believe there would be significant drop in water usage which could be confirmed by checking meter data from EBMUD.