Final Report

A7 Green Group - Lamp Post Flood Detector

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Abstract:

Flooding is an issue that has plagued the nation, especially the Boston area, for decades. With tropical storms and hurricanes almost every year, it is hard to keep up with which storms are going to cause damage, making it easy to underestimate a "small rainstorm" that turns into a thunderous hurricane. This report describes a product that detects the development of a damaging flood so that city officials can act before it is too late, possibly saving the city thousands of dollars in repairs. The device is powered by a battery connected to a float switch that activates the product when water levels increase, and it uses short message service (SMS) to wirelessly send a message to a city official when water levels reach critical height. The ultrasonic sensor used is accurate in detecting a change in water level, and we recommend installing the system on a city lamp post at or above three feet off the ground.

Introduction and Problem Statement:

The goal is to design an outdoor device to be mounted to lamp posts that measures water levels, detects potential flooding, and alerts city officials. Our client requested a flood detection device that will be mainly implemented in the Boston Seaport area. He requested that the device alert himself or city workers when flood levels increase, and he does not mind if he needs to install a communication device (like a telephone or pager) in his office to receive these alerts. The Boston area has temperatures that range from -10°F to 100°F, and rainstorms are common. Thus, this is a serious issue that our device can help solve. By alerting city officials before floods worsen, this device can help to prevent damage in certain areas.

This device will not only save the city money, but it will also protect its citizens' property, families, and belongings as well as increase general satisfaction. The manufacturing process of the device is relatively inexpensive, and, by alerting city officials of flooding in certain areas, this device also saves time that would otherwise be spent scouring the streets for flooding and repairing detrimental damages. Some objectives as well as metrics that we attempted to meet are listed below in order of importance.

Objectives	Metrics
1. Measure water level	- Detects 2" to 2' of water
2. Send timely alert	- Communicates to users in less than 1 minute. - Communicates within 10 miles - Begins sending alerts after 4 cm standing water
3. Durable	- Withstand temperature range of -10 to 110℉ - Waterproof - Withstand 10 drops or a 20 lb force
4. Mounted on a lamp post	- Withstand winds of up to 100 mph - Withstand pull force of 50 lb

5. Reliable	- Doesn't rely on grid power - Alert reaches at least 5 miles from flooding
6. Accurate	- Measurement accurate to +/- 6 cm
7. Low-maintenance	- Measured by the amount of time taken to repair or clean - Scale: Total Points: 10 - (# minutes to repair)/30
8. Easy to set up	- Under an hour to mount - Pass/Fail: Fail if setup takes over 1 hour
9. Unobtrusive	- Should not interfere with current infrastructure of the lamp post - Does not connect to grid power - Does not weaken lamp post - Zero holes in lamp post - Pass/Fail: Fail if there is a hole in the lamppost

Alternatives Considered and Basis for Selection:

Our team morph chart, complete with all the means considered and chosen, can be found in the appendix. We began by considering the possible sources of power and we immediately crossed out wind power due to its high cost. We also realized that using electricity would require plugging our device into the city's power line, which has a high chance of failing during a storm- when we most need our device to work. The water wheel is too mechanical (and outdated); lastly, after ordering the solar panel, we realized that this would be too much work to configure with our time constraint. We decided to power our device with a 9V battery, despite a battery being the least renewable form of energy out of our options. To solve this problem and meet the client's objective of low-maintenance, we included a mechanical float because we only need to power the device when there is a storm. The float will save energy and extend battery life by only powering the device when water levels are above four centimeters. We do not need to plug the device into an outlet, and the option is cost-effective given our budget.

The next part that we assessed was the sensor, which completes the main function of detecting water level. Some alternative means considered were a rain gauge with a mechanical float/potentiometer device that would measure the height of the water as it rose. However, this option would be too bulky and obstructive for a device that needs to fit on a lamppost. Next, we assessed the feasibility of a laser distance sensor that, when placed above water level, can measure the distance of the water from the sensor. However, this sensor can only withstand temperatures from -20°C to 70°C, which means that it cannot function properly in temperatures less than -4°F, which might be a liability. Furthermore, we would have to include a float that the laser would reflect off of because it would not sense water. One more mean we considered was a mechanical tank level indicator, which occasionally also uses a float. These devices are pretty

expensive, though, so we could not fit this in the budget. We decided to equip an ultrasonic sonar distance sensor because, as shown in our modeling results section, this device is accurate when surrounded by a tube. Additionally, the sensor did not require a float, is inexpensive, and was easily accessible because it was in our EK131 toolkits.

In the morphological chart, one can see that we tried to use every means possible to keep water out of our device. This is a very important goal, so we will apply a conformal coat and silicon spray. Lastly, we will place the product in a hard plastic box so that the exterior can be exposed to the elements without damage. We were unable to order O-rings and did not use them in the final design.

The final means we needed to assess was the transmitter. Another main function of the product is to communicate to an official when standing water levels are increasing, but it was challenging to determine a means of which to achieve this. One option was to have a signal sound at the area when flooding was occurring, but this would not be a practical solution since officials most likely would not be able to hear it. Thus, our only option was to somehow communicate directly to the city officials. One idea was to use the Global System for Mobile Communications (GSM) and pair a GSM transmitter with an Arduino Uno. However, the transmitter uses 2G connection, which is now obsolete. Thus, our final means of communication is to use an ESP8266 WiFi module. This device can connect wireless Internet, including phone hotspots. We programmed the module using code written in Arduino IDE, and we used a free online service through which we can use a trigger to send emails and SMS messages. The only drawback with the WiFi module is that the city directors need to provide a WiFi connection.

Results:

Our first completed test was a test of the length that the device can send an alert. During Thanksgiving break, Mitch programmed the device to send a text to Rachel, who was in New York at the time. The text was sent over a distance of at least 150 miles, so this module will definitely work to send messages within 10 miles.

We then tested the actual functionality of the device by recording the water level measurements, which we received through emails. See the data below.

Water height (cm)	Value measured (cm)	Error
9.3	7.55	0.19
13	11.81	0.09
14	13.39	0.04
Note: pipe is 3 feet tall		
measurement on floor is 83 cm		

This was performed by first calibrating the device to see what height it will measure to the solid ground, which is 83 cm. We then programmed the code to subtract the distance from the sensor to the water from 83 cm. We poured water into a large beaker, then gradually increased the water level to known heights. For each measurement from the device we calculated the error. For the first test, there was 19% error, but it clearly decreased with larger heights. In the case of a flood, an inaccuracy of just 2 cm is nearly insignificant.

In our test we filled a beaker, which assumes that the flood will be standing water, but we know that large floods can often have rushing water. To accommodate this, we included a slit at the bottom of the pipe so that running water can flow without ripping the pipe from the post or rushing up the pipe, causing a false reading. Another assumption we made is that the battery will not discharge when the circuit is not closed. Typically, batteries lose power over time, but we chose to imagine that the battery is an ideal battery. Furthermore, in testing our device, we saw that there was a variation in water height due to the displacement of the pipe, so more water led to larger water level displacement. This might cause some error in the reading; however, as mentioned before, small discrepancies are insignificant as long as the city officials are alerted about the destructive flood.

Conclusion:

As one can see from our budget sheet in the appendix, our prototype is pretty cheap and just under $200. However, since we remodeled the design multiple times between orders, we spent much of our budget on parts that were eventually cut, which is not depicted in our budget sheet. This is why the overall cost of building the device is not even half of our $400 budget. These changes also resulted in a cheaper overall cost of manufacturing as well as the ability to make our design more compact. By opting for battery power, a simpler circuit without a board, and less wiring, we reduced cost as well as bulkiness of the design. This prototype was not even $200, so manufacturing in bulk will be much less expensive.

Overall, our design fulfilled most of our objectives, with the exception of “durability” because our prototype was not industrially engineered, so we were hesitant to perform a drop test. This can be easily fixed with stronger reinforcements and a stronger encasement, but we had to resort to an acrylic box of our own crafting. If this product were to be mass produced, we would recommend using an enclosure that passes the IP68 standard and is not transparent. We created the prototype with a clear box in order to display the interior circuitry. One more objective’s success that we were not able to measure was the object’s ability to remain mounted to a lamp post in the wind. A metric that we wanted to test was if it could withstand 100 mph of wind, but this was impossible to simulate with our tools.

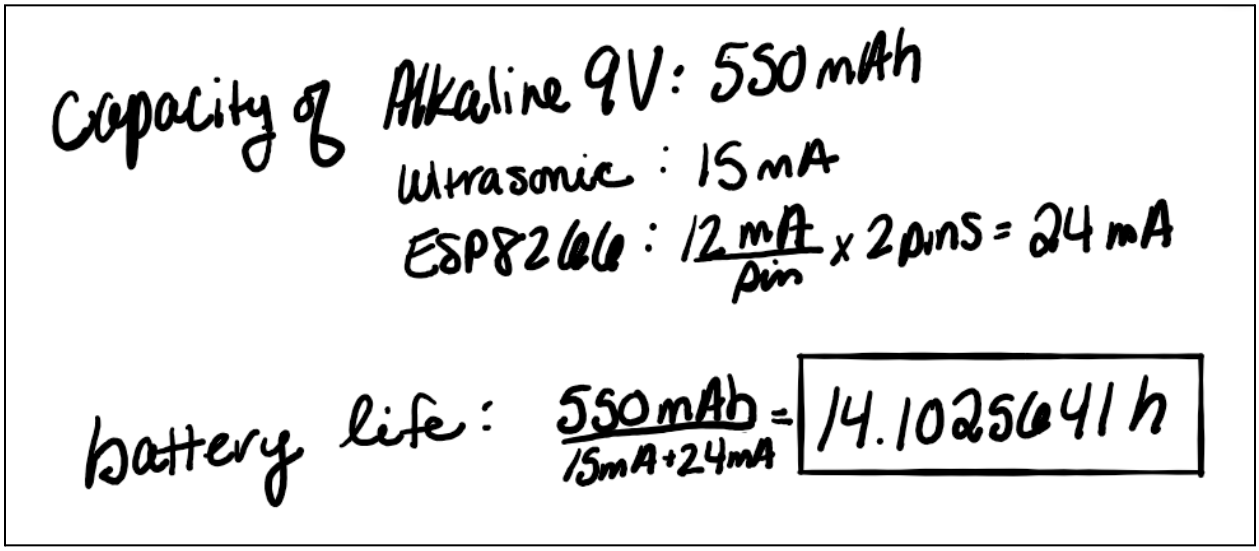
Despite these two objectives, the design was fairly successful in testing, and the results are promising. With an average of about 11% error from three data sets, we are confident in the ability of our device to identify a flood and alert an official quickly. The product is easy to set up and only has to be hooked to the lamp post using the pipe clamp. It is also low maintenance due to the long battery life and the other parts do not need replacement unless tampered with.

However, due to the heating up of wires and soldering loosening up, we recommend an electrical performance test once in 6 months.

Appendix

Specifications and Calculations:

Metrics	Units	Importance	Value/Range
Production Cost	USD	****	$193.14
Water/Dust-Proof	IP68 Standard	*****	Yes
Lifetime	hrs	****	14.1 hrs
Storage Capacity	mAh	**	550 mAh
Weight	lbs	***	~ 5 lbs
Message Sending Length	miles	****	at least 150 mi
Setup time	minutes	***	15 mins
Water Level Measurements	inches	*****	2-24 inches
Message Sending Time	seconds	*****	< 60 seconds



Functions	Means							
Power system	Solar panels	Wind turbine	Water wheel	Battery	Electricity	Float switch		
Measure water level	Rain gauge	Water detection sensor	Mechanical float (w/ potentiometer) 	Variable water resistor	E Tape (liquid level sensor)	Magnetic Float and read sensor	Ultrasonic sonar distance sensor	Laser distance sensor (VL53L0X)
Keep out water	Plastic exterior	Silicone Spray	Conformal Coat	O-Rings				
Does not fall from lamp post (secure)	Screw	Pipe clamp	Belt	Cable tie	Spring/Washer	Bolt/Nut		
Send signal	Radio waves and Transmitter	Light turns on	Audio sounds	SMS Message				

Morph Chart: Each alternative means is grayed out with light gray, and the means that we decided to use are in black.

Modeling Data:

Model 1:

Water height (cm)	Value measured (cm)				Measured Water Height (cm) 86 cm - Sensor Measured Value	Error	Standard Deviation btwn Trials
	Trial 1	Trial 2	Trial 3	Avg			
9	77	77	77	77.00	9.00	0.00	0.00
25	62	62	63	62.33	23.67	0.05	0.67
32	55	55	55	55.00	31.00	0.03	0.00
42	45	45	46	45.33	40.67	0.03	0.67
		Note: pipe is 3 feet tall measurement on floor is 86cm					

Above is our data from modeling the accuracy and precision of the ultrasound sensor used to detect water level. Although the sensor detected the height from the floor as 86 cm when the actual value is 91 cm, the accuracy of the change in water height is nearly perfect, with an average of 2.75% error between trials.

Budget/ Prototype Cost:

Part Name	Quantity	Price ($)
Silicone Sealant	1	$8.99
PVC pipe	1	$14.54
Pipe Clamp	1	$22.33
Conformal Coat	1	$20.00
Battery	1	$13.99
Plastic Box	1	$24.99
Battery	1	$5.99
Acrylic Sheets	2	$19.90
ESP8266 Module	1	$7.39
Ultrasonic Sensor	1	$3.95
Solderable Breadboard	1	$4.50
Jumper Wires	1	$2.25
Breadboard	3 (need 1)	$8.99
Resistors	1	$7.95
Vertical Float Switch	1	$9.52
Pin Headers	10	$9.26
		Total: $187.54

Sketch

