Flood Monitoring and Mitigation Strategies for Flood-Prone Urban Areas
(Technical Paper)

Flooding Mitigation Techniques in Other Flood-Prone Regions and an Analysis of Their Possible Use to Charlottesville
(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science
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Bachelor of Science, School of Engineering

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature *Kiri A. Nicholson* Date 04/26/2020
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Acknowledgements & Comments

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From Professor Gorman:

I am particularly interested in this Capstone project because I am a co-PI on Prof Goodall's NSF-sponsored project in Norfolk. The problem is, of course, both social and technical. For example, if you are able to use sensors to obtain improved data on flooding, what is the most effective way to make sure citizens understand its implications? Could you predict which areas are most likely to flood in a particular storm and then test those predictions with the data during and after the storm? In terms of getting the community engaged in mutual efforts to deal with *flooding, trading zones and interactional expertise would be a good framework: the former for getting citizens to work together, the latter for getting citizens and researchers to communicate effectively by understanding each others' perspectives.*

I did elaborate a little more in the technical portion of the Prospectus mostly due to the below comments, though I did not answer many of the above questions in-depth, as I felt it was out of scope. I did however, like this idea for an STS framework, and chose to incorporate it into my Prospectus.

When I read your prospectus again, I wanted to know more about the sensor technology you are using--it sounded like Lidar, but could be a combination of different technologies. I liked your brief review of gray and green mitigation solutions.

As mentioned above, I elaborated a little on the technical portion of the Prospectus to give more detail.

This is a very important project! I am focusing on climate change during jerm and if any members of your team are in town, I would like to visit some of your sites and talk about your research. I am a co-PI on Prof Goodall's CRISP proposal.

The 8 means a B which I will convert to the correct points for the grade--you can easily raise this to an A by considering the STS perspective I highlighted above.

You can look at whether and how your interdisciplinary team has to establish shared meanings for terms and concepts.
Yes, I agree!
Include pictures of the sensors and show where they are located in your final thesis next semester.

I agree and will do this (as of 4/21/2020 I chose not to do this)

Is there a similar city that is further along in this process? I am sure Charlottesville officials consult with those in other cities facing the same challenges.

I plan on addressing this in my thesis
You are trying to establish a trading zone with experts who work for Charlottesville. Keep track of this process.
Will do!

This deception worries me a little bit—from n ethics standpoint it is better to enroll local stakeholders in the project, let them see data from the sensors. [regarding putting the system in a pipe or ditch to hide it]

Introduction

With the pressing threat of climate change becoming ever more apparent, one starts to consider the personal implications of such a massive problem on our daily lives. An increase in catastrophic weather events is a widely accepted consequence of climate change. More specifically, such events have "become more frequent and intense in the past decades" (Cheng et al., 2017, p. 25). With these changes comes an increase in storms and rain levels. These events, in turn, lead to flooding.

In fact, "[t]he occurrence of floods is the most frequent among all natural disasters globally, which is mainly due to the climate change induced extended periods of high intensity rainfall and rapid urbanization induced changes of watershed hydrology (Ahiablame and Shakya, 2016; Chen et al., 2015; Elliott and Trowsdale, 2007)." (Xie et al., 2017, p. 143). In areas such as Charlottesville, Virginia, flooding is an issue when heavy rainfall is frequent. Efforts to mitigate the impacts of this flooding are already underway in Charlottesville, VA, which are including but not limited to capstone work performed by University of Virginia faculty and students in collaboration with Smart Cville (*Smart Cville*, n.d.). Specific efforts made by this team will be discussed later in this Prospectus.

Flooding mitigation strategies are not a one-size-fits-all solution, and numerous technical, economic, and social factors need to be considered when deciding the optimal implementation for a city, state, or other area. However, it does not make any sense to "reinvent the wheel," so we can look to other areas of the world for inspiration and data on tried and true flooding mitigation techniques. In my thesis I will take a look at flooding mitigation strategies employed in other flood-prone areas of the world, and analyze them and their potential use to the residents of Charlottesville, VA. I plan to use trading zones and interactional expertise as a framework to evaluate these technical, economic, social, and political factors. The concepts for these two STS frameworks were introduced to the author in STS 4500 in Fall 2019. The meanings of these concepts were outlined in class discussions, the Sept. 22, 2019 class forum and a few class readings (Gorman & Werhane, n.d., Collins et al., 2007).

Prospectus[2]

Technical

My capstone team's project is a continuation of a 3-year effort to take a look at flooding mitigation strategies in an urban setting, previously having been focused on Norfolk, VA. In this iteration/forking of the project, we are focusing on flooding mitigation in the City of Charlottesville. Working with the city, we were given one particular residential area with a specific flooding problem to consider. We were given background information on the infrastructure and possible causes of the flooding in this area.

After being assigned this capstone project, we quickly broke into three subteams: (1) an Infrastructure Team made up of 2 Civil Engineering students, (2) a Flood Mapping Team made up of 2 Systems and Information Engineering students and (3) a Sensor Team made up of 2 Systems and Information Engineering students and 1 Computer Engineering student. Even the make-up of our interdisciplinary team provides a basis for a possible trading zone. My subteam, the Sensor Team, received the physical legacy system provided by the 2018-19 capstone group. The sensor system used an ultrasonic sensor that is able to detect changes in depth directly below itself (a round sensor a few centimeters in diameter) to measure water levels of an area beneath

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[2] Parts of this prospectus were re-written to be submitted with this Portfolio

the sensor, and was mounted in a box that is intended to be attached to a light pole or similar structure. Here it can remain in place and measure water levels continuously. A microprocessor (Things Uno), 10000 mA/hour battery, and solar panel were also included in this subsystem. We were also provided with some database infrastructure as well as a GitHub repository of scripts used for pushing and pulling data between the sensor and the database system. My team then started to evaluate the progress made by the previous team(s) and scope the direction that we wanted to take the project in the next 8 months.

In this semester (e.g. by December 2019), we aim to have the ultrasonic sensor system fully functional – meaning it can both sense changes in water levels and communicate with the database using low-power and long-range technologies (more specifically, LoRa communication protocol). Additionally, we will ruggedize and waterproof the housing, as well as pitch and get approval for which location(s) we can deploy these sensors in. Possible locations include the sites within the University of Virginia and/or the Charlottesville community. By May 2020, we hope to have had several of these sensors in place for 1-2 months and have been able to troubleshoot and perfect the system, as well as collect data[3].

We aim to have the system be self-sustained as much as possible. This primarily means that battery life should be around 20 days, and it should not require maintenance during this time. We placed particular emphasis placed on a lack of resident impediment, meaning we want to keep the apparatus hidden from resident view in order to cut down on (1) uncomfortable

[3] Disrupted by COIVD-19 response

questions regarding a ‘monitor’ being installed in neighborhoods and (2) the potential for damage or vandalism if it were more visible. Further conversations with the City of Charlottesville indicate that we should consider installing the sensor(s) inside pipe(s) easily accessible by an open pipe entrance (i.e. into a drainage ditch).

STS

As is this case with any comprehensive engineering problem, solutions cannot be chosen for their technical merit and technical merit alone. Many economic, social, and political implications need to be considered along with technological factors. In my thesis, only mitigation efforts will be considered, as opposed to disaster relief efforts. These efforts include “actions taken to reduce loss of life and property by lessening the impact of disasters” (United States. Congress. House. Committee on Transportation and Infrastructure. Subcommittee on Economic Development, 2014, p. iv). When compared to disaster relief, mitigation has been shown to both save lives and save money in the long run (United States. Congress. House. Committee on Transportation and Infrastructure. Subcommittee on Economic Development, 2014, p. iv). In fact, in a study, “Potential Cost Savings from the Pre-Disaster Mitigation Program,” Congressional Budget Office, September 2007, mitigation has been found to be cheaper than disaster relief by “an overall ratio of 3 to 1” (United States. Congress. House. Committee on Transportation and Infrastructure. Subcommittee on Economic Development, 2014, pp. iv-v). In addition, it seems that the responsibility of these mitigation efforts falls squarely on the shoulders of our government and other authoritative bodies. Harvatt et al. express a distrust of the individual, noting that there is “evidence that householders living in natural hazard areas often fail to act, or do little to lessen their risk of death, injury or property damage (e.g. Kunreuther 1978; Peek and Mileti 2002; Siegrist and Gutscher 2008)" (Harvatt et al., 2011, p. 64).

Groups such as Wetlands Watch and the Elizabeth River Project in the Hampton Roads, VA area provide some basis of a model for effective grassroots advocacy and education efforts in flood-prone areas ("Wetlands Watch", n.d., "Elizabeth River Project", n.d.). I plan to use trading zones as a framework to analyze the dissemination and understanding of this information as it makes its way into the community.

As was stated in Harvatt et al., trust is very important when conveying risk, and there is "evidence that those unsure about the source of warnings tend to rely more on their social networks than on official communication (Drabek 1986; Parker and Handmer 1998)"; so it is obvious that if efforts come too heavily from only the government or another large, disconnected body, their warnings may not be taken seriously (Harvatt et al., 2011, p. 65). In one work, it is suggested that the "reason for farmers' lack of behavioural engagement is the invisible and intangible nature of climate change, often leading individuals to deem it 'psychologically distant' (Kollmuss and Agyeman 2002; Pidgeon and Fischoff 2011)" (Hamilton-Webb et al., 2017, p. 1381). Therefore, it is imperative that our cities and states are able to find and employ viable mitigation strategies, and we not depend on the citizens to perform this important function.

When infrastructure is being looked at with regards to flooding, there is one major distinction that should be made, the one between: (1) gray infrastructure and (2) green infrastructure. According to USEPA (2016), green infrastructure includes things "such as Green Roof, Bio-Retention Cell, Rain Barrel/Cistern, Vegetative Swale and Permeable Pavements" that "reduce runoff, minimize pollutant discharges, decrease erosion, and maintain base flows of receiving streams" (Xie et al., 2017, p. 144). Also according to USEPA (2016), gray infrastructures, however, include "gutters, storm sewers, tunnels, culverts, detention basins, pipes and mechanical devices" and are "used collectively in a system to capture and convey runoff" (Xie et al., 2017, p. 143). It is also acknowledged that effects of flooding and other disasters are often felt more in developing countries (Attfield & Beattie, 2019, p. 4).

Conclusion

In conclusion, we know climate change to be a pressing issue today that is going to affect our way of life for many generations to come. It is therefore very important that we as citizens and our governments consider fully how best to respond to the many consequences of climate change, including but not limited to providing ways of mitigating the effects of these consequences. In Charlottesville, Virginia, specific work is being done to look at issues of flooding. My capstone team was given the opportunity to work on a specific residential site where flooding is a persistent issue in times of major precipitation. This site is not easily relieved of its flooding issues due to a number of social, political, economic, and physical barriers. Therefore, this provides an excellent environment to look at possible new strategies that could be employed on a wider scale in Charlottesville. In doing so, it is important that in both our work this year and beyond, we consider all of the implications of potential strategies and mitigating techniques, and we select the best ones for our community. In my thesis, I plan to explore these factors and use trading zones as my STS framework to do so.

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