Prospectus

Flood Warning Systems for the Local Charlottesville Community
(Technical Topic)

An Examination of Cultural Relationships with Flood Management in Bangladesh
(STS Topic)

By

Abdullah Mahmood

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Technical Project Team Members:

Loza Asmare
Glen Mitchell
Kwadwo Tenkorang
Conor Todd

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.

Signed: Abdullah Mahmood
Technical Advisor: Jonathan Goodall, Ph.D.
STS Advisor: Sean Ferguson

Introduction

Along US-29 is a watershed area in the city of Charlottesville, VA which drains water to a creek in the Greenbrier park area. During periods of heavy rainfall, the watershed area can overflow, causing damages and delays to the residents in the surrounding area. In order to protect the surrounding area and its residents from damages caused by these storm events, our capstone project aims to create a scalable flood warning system by using hydrology and hydraulic models to predict floods based on rainfall forecasts using data from various real-time sensing devices. In regions where climate change is rapidly increasing the frequency and severity of extreme flood events, e.g. Bangladesh, there already exist cultural frameworks for flood management strategies. However, there lie many, increasingly complex political and cultural influences with respect to current damage mitigation techniques.

The main goal of the capstone project will be to provide a scalable solution for a flood warning system in Charlottesville to be provided for use by Albemarle County. Forecasts and models in the flood warning system will depend upon a combination of utilizing serverless cloud technologies and real-time sensors collecting data including, but not limited to, stream levels, soil moisture, and rainfall. Serverless computation and use of many, cheap IoT devices for measurement are the core of making this project scalable. Once a solution is achieved for the local Charlottesville community, it may be able to be extrapolated for a universal solution in regions where floods are common and economic resources are tight.

However, a scalable, universal flood management solution will not be the sole solution for mitigating damage dealt by extreme flood events, as there are many political and cultural hurdles to consider as well. In countries where there already exist flood management strategies, the implementations are not as strong as they could be. In this prospectus, I analyze the connection and implications of cultural ties, political influences, and motivations for flood management in developing regions, specifically the South Asian country of Bangladesh.

Technical Topic

Strong storms and intense rainfall threaten watersheds with poor stormwater infrastructure with damaging floods that overwhelm the local stormwater system. In Charlottesville, VA, the watershed along US-29 draining to Meadow Creek in Greenbier Park was identified as a problem area with potential to improve. Massive storm events can cause damaging floods in the area, negatively impacting the local residents. A climate change model for central Virginia anticipates extreme flooding as one of the risks within the next few decades (Stuart, 2020). By developing different models and real-time monitoring and alerts for this particular watershed, guidance can be provided to Albemarle county officials to reduce damages in this area caused by storm events. This system can then potentially be replicated for wider use in the county.

Under the guidance of Jonathan Goodall, Ph.D, Professor of Civil Engineering in the Department of Engineering Systems and Environment, the flood warning systems capstone team and I will develop a scalable flood warning and modeling system. This system will provide predictive flood modeling with an updated hydrology model of the selected watershed and data collected from real-time IoT sensors. A website with live data visualizations and analysis will also be among one of the tools provided to Albemarle county officials. Using these tools, a recommendation can be made to residents and other stakeholders in the area if a flooding event is predicted ahead of time using available weather forecasts and sensor data. A similar concept is already in use with the StormSense project in Virginia Beach, VA, able to accurately predict flooding up to 36 hours in advance (Davis, 2018).

The updated hydrology model will require physically observing certain sites in the watershed and GIS data available from an Albemarle County. They will be used to analyze and map different geological properties of the region. From this, patterns of stormwater flow can be observed. The next component for predictive modeling is creating statistical forecasting models for rainfall using sensor data and weather forecasts. Once a significant statistical model is built, the combined models will be used to simulate stormwater flow in the watershed. The completed simulation should identify bottleneck areas in the current system infrastructure and allow county officials to issue accurate assessments for action to mitigate damage.

The predictive modeling will require computational resources in order to run the simulations and analysis. For this, serverless architecture will be used, provisioned by Amazon Web Services (AWS). Traditionally, the whole computational system could theoretically be done on one machine, but with serverless cloud computing offers an overall better solution. Using AWS, our project will have lower overall costs, be easily scalable, be quicker to deploy, and have high availability (Serverless on AWS, n.d.). This is done by paying only for the resources used, quickly deploying dedicated infrastructure for the system, and not having to maintain the underlying hardware, which reduces the overall complexity of the project. Being highly available means if a very extreme flooding event were to occur, the flood warning system will have limited downtime as the AWS can quickly fall back to other available servers in the region. Currently used AWS tools for the project are Lambda and Aurora. The Lambda functions are a low-cost way to query sensors, update measuring frequency of the sensors, transform data, and upload it to the Aurora MySQL database. My main responsibilities for the capstone project will be dealing with creating and deploying the serverless infrastructure and software and ensuring best practices for scalability.

STS Topic

Annual floods in Bangladesh affect an average area of 20.5% of the country, up to 70% during extreme flooding events. These flooding events create economic harm to the developing nation (Mirza, 2002). Strong flood events and poor disaster management can be tied to Bangladesh's cultural history and identity as some of the main causes of its separation from Pakistan. According to Cook (2010), the poor response to the cyclone in 1970 was an example of incompetency of Islamabad's disaster management, followed up by the famines in 1974 as a result of those poor control strategies. This famine also shifted the main objective of flood management in the country towards boosting its agricultural sector and development to reduce food insecurity. According to Elahi (2017), by 1974, Bangladesh was a food deficit country which depended on import of agricultural goods. Due to Bangladesh's international trade relations with Cuba, the United States withheld food aid to the country. The combination of flooding disaster and political disaster created the conditions for the devastating famine, likely being the main reason for Bangladesh to shift its focus towards agriculture as a flood damage mitigation strategy.

On a smaller, more local level, discussion and action surrounding flood management strategies have relatively recently become more and more critical. Up until the first half of the 20th century, flood management was based on local governance and culture instead of national as the colonial strategy at the time was to be more hands off from planning (Cook, 2010). Flood management was also not as imperative as it is now since the population was significantly lower and high-risk flooding areas did not have to be occupied by locals. As the population in the country grew later on in the century, more and more homesteads were developed in flood prone areas. With this, household-level (autonomous) adaption measures for flood management/cost mitigation arise. The traditional systems of "living with floods" starting shifting to incorporate the "controlling of floods" during colonial engineering and especially later on with national water planning (Rammelt, Masud, Masud, 2018).

In a case study of a village in the Satkhira District, Fenton, Paavola, and Tallontire (2017) observed the current autonomous adaption measures of villagers. In the case study, they aimed to see whether a planned adaption strategy would be more beneficial long-term rather than the short-term, reactive incremental adaptions by the villagers. In recent decades, costs due to flooding in the area have drastically risen. Nearly all the villagers who used to plant cash crops in the summer, own livestock, and pay off mortgages on their properties (signs of prosperity in the area) have had to fully change their way of living due to increased flood severity. During the summer months, flooding was so intense that the villagers were unable to cultivate cash crops. Unable to make profit from the summer months, the villagers had to revert to selling their rice cultivated in the winter, mainly used for their sustenance. This caused food insecurity, leading to cultural shift of domestic migration of male villagers in summer months to barely scrape a portion of their former income. This domestic migration is seen by Fenton et al. as a negative adaptation strategy. Instead, with the assistance of the government, a proper solution would be to develop a long-term planning goal for preemptive adaptation rather than the existing reactive adaption.

Some farmers have successful autonomous adaptation for flooding. For example, the raising of ducks instead of chickens is a positive cultural adaptation for rural farmers. However, it is the extreme flooding events that cause an irreparable loss for the marginal subsistence farmers, leading to a vicious cycle of constant downsizing of land ownership (Younus & Harvey, 2014). Some cultural shifts recommended by Younus and Harvey in favor of supporting these farmers are to research and provide seedlings for crops with shorter maturation periods, increase access to the distribution of farming labor materials, and increase access to farming loans/subsidies. They also assert that an essential time for the Bangladesh government to support farmers is the post-flood period.

Next Steps

Throughout the end of this semester and the beginning of the spring semester, several tasks need to be completed. For the technical portion, the combined hydrological and statistical forecasting model need to completed. The AWS infrastructure needs to be finalized and deployed alongside a CloudFormation template, which allows for one-click deployment of AWS services. A basic website for interactive visualizations needs to be launched. For the STS portion, as mentioned earlier, there are many NGOs that are invested in implementing improved agricultural and flood management practices and resources in Bangladesh. Many of them seem to have too narrow scopes, which may lead to failed projects and waste of resources. In the following thesis, I will focus on best practices for governmental intervention, NGOs, and local-level autonomous adaptations for flood cost mitigation strategies.

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