Internet of Things for Water: Real-time Water Level Sensing to Support Flooding Emergency Management: UVA/Charlottesville as a Case Study

Analysis of the factors that affect homeowners being denied flood insurance coverage

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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.

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General Problem

Flood losses preventing mitigation strategies

Water is a fundamental component of everything relating to humankind. It is essential to human bodies, lying in human consumption, required in processing human activities, and used in producing food and agriculture. Nevertheless, excessive water can cause problems for human living, infrastructure, and agriculture. Flooding has been a problem for humans for a long time, especially for people who live in coastal areas and flood plains due to the water surge. People in the early days tried to settle near water bodies to access water easily. Nowadays, the pipe system allows water to be transported directly to people's homes, reducing the demand for waterfront residency. Even though people settle further away from a waterbody, a hurricane or a big flooding event such as a 100-year flood can devastate their home within a few days. Since flooding can cause many losses, people try various methods to solve the water problem. They are starting with building flood prevention infrastructure such as dams and weirs to prohibit and control the water allowed to enter the land. Policies and decision-making, such as flooding insurance, can be an option to help reduce losses due to unintended circumstances. Also, inventors try to introduce new instruments, like water sensors, to keep real-time tracking amount of water and evaluate the change of water.

Both two studies focus on tools that are used for flood mitigation. My capstone is related to water sensors used for monitoring the amount of water, tracking the data on a network, and analyzing the water sensitivity of an area. UVA and Charlottesville communities are our focus study. This study about water sensors is more about flood prevention strategy.

While my STS research will focus on flooding insurance that can reduce property losses after a flood occurs. As many homeowners deny being under flood coverage even though they

realize climate change, it will be helpful to understand why they do not participate in NFIP insurance plans and what factors are.

Technical Research Problem

Internet of Things for Water: Real-time Water Level Sensing to Support Flooding Emergency Management: UVA/Charlottesville as a Case Study

Flooding has become more severe because of climate change. It can impact a large number of public infrastructure and properties each year. Cities are looking for ways to locally mitigate this issue (FEMA Resources for Climate Resilience, 2021).

There are several ways to prevent and reduce losses. One method is providing reliable information to the public about their risk through flood risk maps. The map is an essential resource for municipal planning, emergency action plans, flood insurance rates, and ecological studies. It can be created by Geographic Information Systems (GIS). GIS is software that can visualize a general overview of a specific area, analyze a flood map, and generate a flood risk map. However, GIS must be used together with a hydraulic method to estimate flood profiles within a given return period (Demir & Kisi, 2016).

Data from various resources must be gathered and collected to create a flood map or mitigation plan. Since the weather fluctuates, data should provide sufficient points to be evaluated and frequently updated to generate a better precision map. It is difficult to collect data using humans in situ within these requirements. Therefore, using sensors to help collect data can be an option to get more precise, on-time data and lessen human work.

Our project combats this issue using water sensors connected to the Internet of Things (IoT) network. IOTs are a modern world revolutionary. The main concept of IOTs is to connect

objects' data collection through seamless systems. Each object will embed with a sensor. Sensor nodes that store data at an object can connect, transmit and exchange data with other devices and systems over wireless communication (Gunasagaran et al., 2015). In this case, we will use IOTs to continuously monitor various factors, such as water level, and give more insight into hydrological systems before and during storm events. Data from IOTs is received and stored in the Google Cloud Bigquery database. At the same time, the illustration of data in graphs will be on Grafana, a multi-platform open-source analytics, and interactive visualization web application.

As a case study area, we are more explicitly diving into determining the correlation between water level, rainfall depth, and soil moisture within the UVA/ Charlottesville community. From the correlation, we will determine the flood risk within in UVA/Charlottesville boundary from our analysis with a hydraulic method calculation in HEC-HMS. The sensor data and the real-time forecast precipitation data will be used as inputs in our model. Then, if predicted rainfall exceeds a threshold level, it will trigger a warning system in the user's interface.

Our team has been divided into three subsections to investigate this problem: power management, cybersecurity, and hydrology. The power management aspect explores the impacts of interval sample frequency on the sensors' battery levels. The cybersecurity person is investigating which server provides the best secure connection. Lastly, the hydrology aspect plans to create a flood risk model of the area, gaining further perspective on how water travels through the UVA/Charlottesville area. The civil engineering students are working together on the hydrological part, so that will be our focus moving forward.

For my part as a civil engineering student, we first determine suitable locations within UVA/Charlottesville boundary to place the sensors by using ArcGIS. When the water and soil moisture sensors are placed, we will receive continuous data about the water level and soil moisture. As for rainfall depth, we will use a rain gauge located near the streams, either the rain gauge at Scott Stadium, Observatory Hill or Venable from Weather Underground. We can also pull data about 6-hour Charlottesville forecast precipitation from NOAA's Climate Data Online database. In the end, after we obtain all the necessary data, we can generate UVA's real-time flood risk map.

STS Research Problem

Analysis of the factors that affect homeowners being denied flood insurance coverage

Nowadays, the climate has become unpredictable that the climate change rising drives natural disasters to come often and high hazards. Therefore, some flood prevention mitigation methods, such as flood control infrastructure and analyzing tools, are insufficient to endure the losses. The natural disaster has impacted several houses, then property losses due to the impact are a large amount of money. As a result, a mitigation method such as flood insurance can be an option to ensure that every household gets aid to repair the house in case a big flooding event occurs.

Typically, standard home insurance policies do not cover any flooding that originates outside of a home. Then, the residents choose to purchase a flood insurance plan. The majority of flood insurance options can purchase through the Federal Emergency Management Agency's National Flood Insurance Program or NFIP (Collier et al., 2022)

Due to the recent Hurricane Ian, 1.8 million households in nine counties of Florida, only 29 percent have federal flood insurance. Therefore, after President Joe Biden declared disaster areas to make residents eligible for federal aid to pay for minor home repairs, it left 1.3 million households without federal flood coverage. They found out that most regions with high risk have yet to have coverage. Also, people in the low coverage percentage area have high incomes (Frank, 2022).

From this recent news, we can see that flood insurance is still not a majority choice for people who live in the United States. Then, it will be helpful to have a better comprehensive from all flood insurance sellers, buyers, and NFIP perspectives.

In my STS study, I will first collect data about FEMA flood maps and programs, which can be tools for homeowners to decide to analyze. The resources to support this can be studies from FEMA or any research publishers. Then, I will focus on several case studies that show the social impacts that prevail on people getting flood insurance and find the common pattern across the case studies. Literature pieces of evidence to support arguments in this project can obtain from research publishers, polls, and news. Literature pieces of evidence to support arguments in this project can derive from research publishers, polls, and news. As flooding can occur anywhere, my area scope will be within the United States.

Several studies about NFIP attempt to urge many people to participate in flood insurance programs in the United States, one of which is my area of interest. Over the last summer, I have researched the Community Rating System (CRS), which is one of NFIP's voluntary incentive programs that recognizes and encourages community floodplain management practices. NFIP will provide a premium discount to communities that exceed the CRS program's threshold activities (Frimpong et al., 2020).

We recognize that the insurance costs impact homeowners to buy insurance. The house size, flood risk, and demand shape the price of insurance premium cost. Especially in a flood-prone area, many property owners cannot afford a high-premiums plan. Also, new residents, when they build or moved into their homes, they need help understanding the risks (Jerolmack, 2022). This statement can proof by a study by Landry et al., who state that the "Consumer Insurance Survey revealed that 43% of homeowners mistakenly believed major rain-induced flooding was covered under their standard homeowners' policy. Many consumers may have limited information about their risk or may have skewed subjective perceptions of the likelihood or consequences of risk. U.S. flood maps are often outdated and do not accurately reflect risks" (2021).

Lastly, I will investigate the social impacts on homeowners' decisions, including social norms, values, beliefs, and behavior, using Pacey's Triangle (Kunreuther, 2021). Some homeowners feel that they are forced to purchase flood insurance. Sometimes numerical factor such as risk and cost has less impact on the decision. This statement is supported by Lo's study, which says, "the factors that caused Queenslanders to buy flood insurance found that ownership was unrelated to perceptions of the probability of floods, but highly correlated with whether residents believed there was a social norm for the insurance" (2013). According to the argument, these groups tend not to use the flood map as a source in their decision but instead use their social norm experiences. It remarks a question about what can be background stories of a group of people that drives them to rely on themselves rather than the flood map.

Conclusion

Flood insurance is an only flood mitigation strategy that can be accessed at every household level. My STS research project will unfold people's ability, interest, and willingness to get prepare for flooding event. Then, extending to a larger scale, my technical project will use sensor and IOTs technology applying to a real case study of UVA/Charlottesville community. The sensor deployment is a part of public flood prevention

As a result, at the end of this project, I expect to have a better standing on how flood losses prevention mitigation strategies can be conducts both for individuals and public sections. Also, I would like to find a conclusion on whether the flood prevention strategies can be considered as a Sociotechnical system or not.

Citation

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