FIGHTING FLOOD RISKS WITH LIDAR-BASED EARLY WARNING SYSTEMS

SOCIAL CONSTRUCTIVISM ON FIGHTING FLOODS AND INJUSTICES OF CLIMATE CHANGE

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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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INTRODUCTION: ADDRESSING THE RISE OF FLOODING

The concept of water in Vietnam is an extremely complex relationship. In 2022, Vietnam was hit with one of the heaviest flooding seasons ever encountered. Extensive flooding ravaged across Vietnam, leveling infrastructure and crops (Red Cross, 2023). Communities dependent on riversides and coastlines for economic stability collapsed and were forced to migrate to cities, uprooting thousands from their homes (Miller, 2020). Especially alarming, flooding has only trended worse in Vietnam. The UN reports that while it is difficult to pin everything on climate change, natural disasters across the Earth have doubled in the last twenty years (Earth.org, 2020). However, with the annual wet seasons, flooding is embedded into the culture: water from floods create land suitable for rice cultivation, an economic pillar of Vietnam. However, floods are beneficial in moderation – major floods can wipe out homes and rice fields. And unfortunately, while flooding has always been accepted as the norm, recent trends suggest that greater catastrophic floods will occur and sea levels will rise, destroying more than just the infrastructure of these communities, but the cultures, traditions, and livelihoods (Denchak, 2019).

Engineers have wrestled with ways to mitigate flooding damages for centuries – previous work has focused on preventing damages while flooding occurs. This includes physical barriers to stop water flow, such as levees and dams, or through pumping stations. However, it has been found that attempting to mitigate flood impacts through infrastructure designs have not always been effective and can introduce unanticipated complexities that must be planned beforehand (Hoa et. al., 2008). As such, this capstone project, the Floodwatch project, is focused on predicting the risk that a flood will happen before flooding occurs. The goal is to build a LiDAR-based sensor that can collect data on rainfall, temperature, and other relevant data. Deploying these sensors, regions all across Vietnam will be covered, data will be transmitted to project databases and will be used to train machine learning models that predict flood risks based on current weather conditions in a region. Risks are displayed on a web application, easily accessible online and provided to local officials in Vietnam partnering with the project, and can alert users when regions are in dire risk of a flood. If one can warn vulnerable communities days before a flood occurs, then the evacuation effort enabled will save a significant number of lives and allow time to plan for physical strategies to block flooding damages.

These efforts aim to utilize machine learning and LiDAR sensors to reliably collect and transmit data to be used in models in the fight against the damages as a result of catastrophic flooding in Vietnam. This capstone work will address the inefficiencies of current technologies employed, which can be analyzed using social construction of technology. The project aims to better serve the cultural values of local communities than previous methods. The impacts of this work can help reverse economic, health, and social injustices faced by these communities.

BUILDING EARLY WARNING SYSTEMS WITH LIDAR: FLOODWATCH PROJECT

The use of early warning systems to fight floods has been on the rise due to advances in machine learning. These existing systems have relied on different techniques to collect rainfall data: a group used cameras to obtain images of floods, converting these images to create prediction models (Riyanto et. al., 2019). However, these models are not cost efficient, especially in transmission of data. Other technologies include collectors that track the rainfall passing through the sensor to calculate water depth.

This project's approach differs from these two previous methods in two ways: the transmission of data, and the technology used to measure rainfall. Firstly, the project's sensor uses LiDAR: LiDAR stands for *light detection and ranging*, shooting a beam of light from the sensor, traveling until it encounters an object which reflects it back. Once the reflection is received back by the sensor, the sensor utilizes the *time-of-flight principle* to determine the distance between the sensor and the object that the laser encountered. This principle is based upon the constant speed of light, using the time for the light to travel from the sensor to the object and back to calculate the distance traveled (Wandinger, 2005). This can be taken advantage of to determine water depth as well – by pointing the sensor into water and determining the distance to the bottom of the pool versus to the water surface, we can determine the depth of the water. Another advantage of using a LiDAR-based sensor rather than sensors that collect rainfall is that sensors can be deployed on the undersides of bridges, on lampposts, and other structures situated out of the way of daily human activities, avoiding any disruption of traffic or possible tampering to sensors both intentionally and unintentionally (Paul et. al., 2020). The old gauges of this project, which collected rainfall, required deployment on the ground, leading to concerns on its reliability due to the need to deploy in urban areas.

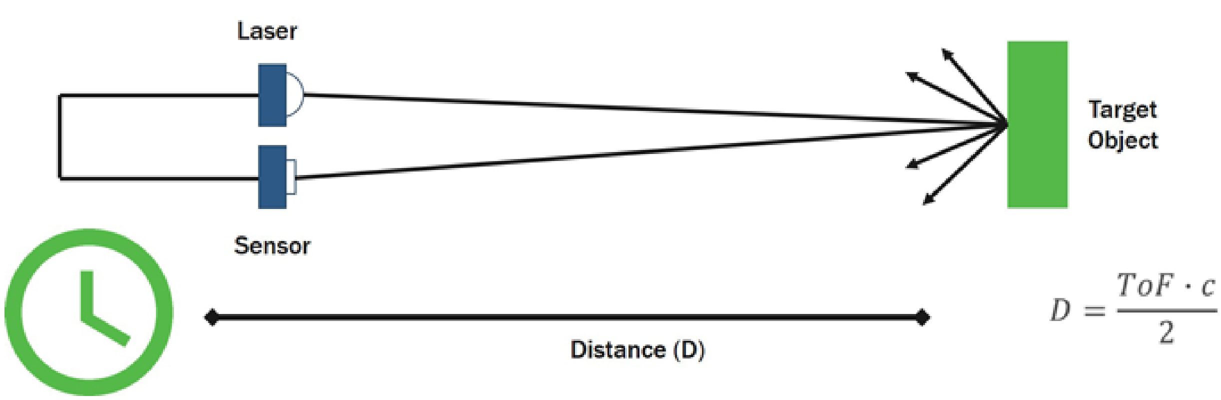

Figure 1. An illustration of how LIDAR sends and receives lasers to calculate distance, of which ToF stands for *time of flight*. (Source: LIDAR News, 2021).

After collecting this data, the LoRAWAN network protocol (*long range wide area network*) is used to transmit our data to the project database hosted online. LoRaWAN is extremely cost efficient, especially due to its low energy consumption – the sensor can be programmed to transmit one packet per specified time interval (Blenn, 2017). It uses much less energy than WiFi, making it possible to scale across Vietnam. It is also easily maintainable by local volunteers due to wide standardization (Basford et. al., 2020). Through firmware code on the sensors directing them to transmit through LoRaWAN towards a gateway, the data is routed to the project database, from which the machine learning team pulls data to train the models.

With a reliable early warning system in place, local communities will now have time to prepare for floods, allowing them to plan physical barriers and evacuations, and brace infrastructure and farmland for impact. This will remove the need for immediate forced migrations of communities at risk, and save millions of dollars in recovery for predominantly low-income communities, addressing social injustice introduced by climate change.

SOCIAL CONSTRUCTIVISM ON THE FIGHT AGAINST CLIMATE CHANGE

The concept of water is complex in Vietnamese tradition. Water from floods may be thought of as bringing upon destruction and harm– rice yields are expected to reduce by 71% by 2100 (Vien et. al., 2011). However, almost paradoxically, Vietnamese communities have embraced water, building homes in vulnerable regions such as the Mekong and Red River Delta (the two most densely populated regions in Vietnam), and traditionally depending on fishing and lifestyles dependent on water (Ngoc et. al, 2022; Nguyen, 2023). Vietnam even has an art form called *water puppetry*, a folk tradition telling stories, performed in water (Vietnamese Immigration Services, 2023). And especially, floods bring water to create marshes, allowing for the perfect rice farming conditions, a major economic dependency for families. This complexity changes how one can address climate solutions in Vietnam.

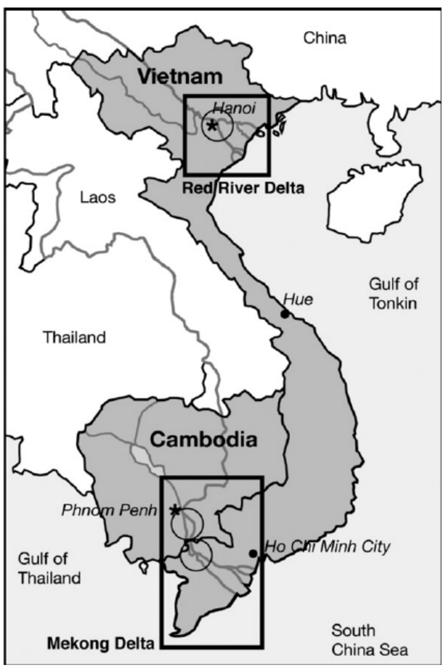

Figure 2. A map of the Mekong and Red River Deltas, the two most populated and vulnerable regions in Vietnam for flooding (Source: Berg et. al., 2007).

How have previous solutions failed? To reason why, we will utilize *social construction of technology (SCOT)*, a framework analyzing technology from which societal standards, values, and human actions shape technologies and their "successes." Technologies have an *interpretive flexibility*, where social values change how technologies are perceived or used, or force redesigns until the technology reaches *closure*, a successful design that has addressed the concerns of each stakeholder group (Pinch, et. al., 1984). Using SCOT, analyzing Vietnam's cultural values reveals that flood mitigation techniques Americans may see as intuitive or useful in American use cases can be ineffective or damaging in Vietnam, and often rejected, an example of the interpretive flexibility of these solutions due to culture. Levees and dams reroute water away from rice fields that communities depend upon and cause another community to bear the flood downstream (Hoa et. al., 2008). This phenomenon is apparent in Vietnam due to cultural values leading to communities densely clustering in deltas. Western strategies for infrastructural changes only make the issue more complex in Vietnam. As Hoa shows through flooding simulations in Vietnam, physical barriers are ineffective long term, and even in the short term, cause unanticipated damage to other surrounding communities without proper planning. Instead, the use of early warning systems like mine has arisen to address this. These face interpretive flexibility as well, with Vietnamese partners providing concerns about how groups would react to deployment of our first design in cities, leading us to move towards LiDAR-based sensors. Early warning systems place the focus on preparation and evacuation, providing time for communities to plan and protect themselves in ways that better serve their values. Yet, closure has not been met – while they serve immediate flooding impacts, they fail to address the impending future of rising sea levels, causing entire regions to soon be underwater.

This reveals the injustice faced by many – those who face the greatest threats due to climate change are countries who contribute the least to it (Miller, 2020; European Environment Agency, 2023). Vietnamese communities will face forced migrations from the deltas, leaving behind their connections to people, livelihoods, and their homes. In addition, lower income communities are more vulnerable to floods – within a localized region, they are more likely to be settled in most dangerous areas for flooding, and are least able to prepare and recover from floods due to lack of income (Bangalore, 2019; McElwee et. al., 2017).

RESEARCH QUESTION

Under these injustices, it is hard to ignore the voices of those under the burden of climate change's impacts. In comparing the urban youth's sentiment against that of the rural elderly, who hold a deeper connection to complex traditional values, I pose the following question: How and to what extent do traditional cultural values change a person's perception of the risks of flooding, climate change, and its technical solutions? More than half the population is under 35, with a major percentage of the population using Facebook (Kemp, 2022). As such, I will use thematic coding on Facebook posts originating from Vietnam, relying on the digital divide to isolate the desired demographic. I will automate numerous calls to the Facebook API to pull posts, and find substrings containing "floods," "climate," and other related words. Posts that contain these will be thematically coded, with a count for each unique word across all posts. By observing which words are most often used in posts related to climate change, we can gauge the sentiments of the younger population in Vietnam, and reveal the values that are important to the demographic. In contrast, those in rural regions and the elderly rarely access social media, due to socioeconomic factors. The best method to reach these populations is through interviews or surveys, much like McElwee's surveying of rural households for perceptions towards flooding risk (McElwee et. al., 2017). By comparing the resulting sentiment between these two demographics, we can compare how age and traditional values affect sentiments on climate change, and what each group believes to be the best actions to take.

CONCLUSION

It is imperative to continue research into smart city applications such as Floodwatch, with the climate crisis continuing to worsen. Early warning systems can be applied to a multitude of other applications such as air quality monitoring in addition to floods (Basford et. al., 2020). Each of these can play an imperative role in the fight against climate change. For regions facing rising sea levels and flooding such as Vietnam, we strive to build a data collection system taking advantage of technologies such as LiDAR sensors and LoRaWAN to efficiently conserve energy, reliably transport data, but play a monumental role in saving lives through enabling early risk detection, planning, and evacuation. Technologies deployed must also be conscious of cultural values, as incompatible solutions may disrupt or even harm the community it was built to protect. A great focus must be kept on these values and the social perceptions of these solutions by local communities.

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