Smart Sensing Technology and its Aid in Flood Data Analysis for Northern New Mexico

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ABSTRACT

This paper addresses the need for infrastructure protection in Ohkay Owingeh, a tribal community located in a high desert region with a pronounced monsoon season. The extended dry period of 8-9 months makes the area susceptible to flooding during the monsoon season, leading to significant disruptions in transportation, infrastructure damage, and the displacement of tribal members. To mitigate these challenges, the adoption of smart sensing sonar LEWIS technology is proposed. The LEWIS sonar system will enable the detection of flood activity by measuring water level fluctuations. This valuable information will provide tribal members with an alert system to monitor and respond to flood events promptly. Moreover, the data gathered by the LEWIS Sonar will empower the tribal community of Ohkay Owingeh to take control of the current situation and make informed decisions for future flood prevention measures.

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INTRODUCTION

Nowadays, natural causes play a significant role in the deterioration of structures and infrastructures. Natural problems, including aging, flooding, earthquakes, and more, can result in various defects in our infrastructures, both in the long term and instantly. Over the past several years, researchers and scientists have been diligently working to develop a range of methods to identify infrastructural defects or damages in the most efficient and cost-effective manner possible. Throughout these efforts, they have aligned themselves with the latest and most advanced technologies available. For instance, some of them utilized computer vision methods to find structural and infrastructural damages or to enhance the inspector's perception during the visual inspections [1]–[3]. Computer vision methods become the foundation of using other types of advanced technologies such as drones, augmented reality and sensors [4]–[8].

The state of New Mexico experiences two significant environmental challenges on an annual basis. One of these problems pertains to wildfires, while the other is closely linked to the aftermath of these fires, resulting in flooding. In the year 2022 alone, New Mexico encountered numerous record-breaking fires, which further exacerbated the vulnerability of the land to flooding. The high desert terrain of the region plays a crucial role in the occurrence of these floods. Due to its desert-like characteristics, rainfall is scarce for most of the year. However, during the monsoon season, which typically spans from the end of June to early September, the rainfall becomes more consistent, leading to severe damage to critical infrastructure and widespread property destruction. The land of Ohkay Owingeh has also been significantly impacted by these natural disasters.

In 2022, the community of Ohkay Owingeh, along with the rest of New Mexico, experienced significant negative impacts from both fires and the subsequent intensified flooding (see in Figure 1). These environmental challenges have imposed substantial costs on the tribal people, affecting their lives, properties, and infrastructure. However, implementing a smart monitoring system utilizing sensors could help mitigate the detrimental effects of floods and post-flooding events, reducing the burden on the Ohkay Owingeh community.

While a sonar-based monitoring system may not prevent flooding itself, it can provide valuable information to the community, enabling them to make informed decisions regarding their infrastructure. For example, if data from various monitoring sites consistently indicate that a specific area is more prone to flooding than others, appropriate actions can be taken to avoid that area. Ultimately, the decisions and actions taken will be determined by the tribal members of Ohkay Owingeh (A location in northern New Mexico state). The sonar technology effectively collects water level data without risking human casualties, allowing the members of the pueblo to prioritize safety and take necessary measures to protect their communities.

Our research team has undertaken the task of designing, building, and developing sonar sensors specifically for flood monitoring purposes in Ohkay Owingeh. These sensors, known as Low-cost Wireless Intelligent Sensors (LEWIS), offer a cost-effective solution for monitoring the fluctuation of surface water in a particular area. By deploying these sensors, we aim to establish a comprehensive and affordable flood monitoring system.

Figure 1. Post-flooding scenery north of New Mexico state.

The LEWIS sensors can transmit the collected data to a cloud database, enabling users to access near real-time information. This functionality allows for timely decision-making and response to changing flood conditions. Furthermore, our research group has actively collaborated with the tribal people of Ohkay Owingeh to involve the younger generation in the process of building and deploying these sensors. This collaboration ensures that the community is actively engaged in the development of a robust flood monitoring network throughout Ohkay Owingeh.

By combining our technological expertise with the local knowledge and involvement of the tribal people, we strive to create a comprehensive flood monitoring system that caters to the specific needs and challenges faced by the community.

COMMUNITY-CENTERED SOLUTION

Over the past year, the Ohkay Owingeh community has played a crucial role not only in the advancement of the LEWIS project but also in fostering meaningful relationships between the tribal members, our technology team, and all those involved in the project. We have worked closely with various committee leaders who have placed their trust in our work and the technology we have developed. They have graciously allowed us to work on their land, which has been instrumental in the progress of our research.

Furthermore, we have been fortunate to have the assistance of two tribal members who have actively participated in mapping out suitable locations for sensor deployment. They have accompanied us to sites and have obtained special permissions to place the LEWIS sensors in private areas. These individuals have not only contributed to the technical aspects of the project but have also provided invaluable insight into their way of life and culture. Their perspectives have profoundly influenced our approach to collaboration and conducting research on their sacred land (see in Figure 2).

Figure 2. The meeting with community leaders and the research team for project's planning and technology transfer.

SERNSORS' DESIGN, BUILDING AND DEVELOPMENT

Regarding the programming implemented in the Arduino board to build the LEWIS sensors, data collection is of importance for the pueblo of Ohkay Owingeh. The program has been designed with multiple fail-safe mechanisms and backups to ensure data collection even in challenging deployment situations. For instance, if a LEWIS sonar sensor goes offline and disconnects from both the hotspot and the website, the programmed instructions will direct the sensor to continue collecting and storing data on the SD cards integrated into the sensor design. The sampling rate may be reduced, but this allows for ongoing data collection, which can be retrieved by manually accessing the specific site and retrieving the SD card at a later time. This ensures that water level data is consistently available. Additionally, if a sensor goes offline, it will continuously attempt to reconnect to the hotspot, eliminating the need for manual intervention as the sensor will automatically reset itself.

The website design represents another crucial aspect of the methodology employed. The website was created with accessibility and visual clarity in mind, providing users with an easy-to-navigate interface. It grants access to all locations, sensors, and data, specifically tailored for each user. Each location is labeled, and upon selection, users can view the various sensors present, their types, and their operational status indicated by color-coded buttons. The colors indicate whether a sensor has been online for more than 7 days, more than 1 day, is in the process of connecting, or is completely offline. Users can then click on individual sensors to access data such as battery voltage, solar panel voltage, and water level readings. This data enables maintenance activities as needed and offers a comprehensive understanding of weather conditions, including solar panel voltage monitoring. Furthermore, it provides readily accessible water level data that the community of Ohkay Owingeh can utilize.

The communication node mentioned facilitates the connection of our Sonar sensors to the internet. Using the deployed code on the Arduino boards, the sensors send data to the website once they connect to the internet. The communication node is designed with rain insulation, and its contents include a car battery, a hotspot, and a solar panel positioned on the outer shell. This setup ensures renewable energy for the hotspot and a high-powered backup through the car battery, guaranteeing uninterrupted functionality even on cloudy days.

Throughout the various deployments conducted in Ohkay Owingeh, we identified the common factors contributing to sensor shutdowns. To address this, we recognized the vital importance of ensuring that all sensor batteries are charged to a minimum baseline of 4.1 volts.

These efforts in sensor design, programming, deployment, and data visualization have been instrumental in creating a robust and user-friendly monitoring system for flood management in Ohkay Owingeh.

Testing the wireless capabilities of our sensors and ensuring accurate and reliable data visualization on our website are essential steps in the preparation for sensor deployments. Spot checks on all cables are conducted to ensure the quality of sensor builds, and the outer shell of each sensor is examined to protect it from adverse weather conditions. These pre-checks are crucial for the success of the deployment.

In addition to these preparations, mock deployments play a vital role in minimizing human errors during the actual deployment process. Mock deployments involve accessing a test site, attaching LEWIS sensors to tripods, ensuring connectivity between each sensor, the communication node, and the website. The goal is to verify that each sensor is producing accurate data on the website, while carefully documenting timestamps for each actionable item.

The operational aspects of the LEWIS project extend beyond building and programming the sensors. Given the nature of tribal lands, the terrain may not always be stable or suitable for freely placing the sensors. To address this challenge, an innovative design was implemented, utilizing existing tripods and adding a metal platform on top for magnetic attachment of the sonar sensors. These tripods are designed to be highly durable, with stakes for stable placement in the ground, and weatherproof to ensure long-lasting deployments. The tripod design overcomes many challenges associated with securely attaching the sonar sensors in various terrain conditions.

Furthermore, the pre-deployment preparation phase is crucial. Figure 3 showcases the sensors ready for deployment in the field, highlighting the meticulous preparation that takes place before the actual deployment process begins. This includes ensuring all necessary equipment and resources are readily available and properly organized.

By conducting thorough pre-checks, mock deployments, and implementing innovative designs, we aim to maximize the success and effectiveness of our sensor deployments in Ohkay Owingeh.

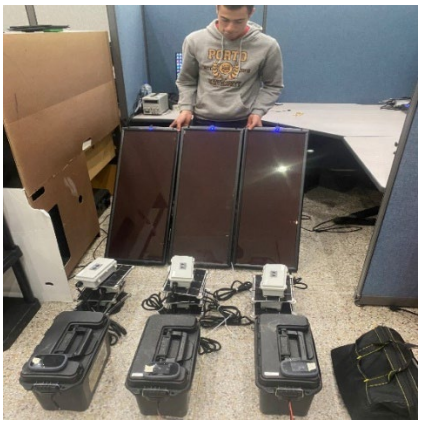

Figure 3. The sensors are ready to deploy in the field.

The implementation of our sensors in Ohkay Owingeh requires additional effort, but with the support of various groups and tribal members, it has proven to be just as functional. One of the key components of deploying sensors in Ohkay Owingeh is obtaining approval for each deployment site. We send our requests to our liaisons in the tribe, who then communicate with the tribe's leaders to seek permission, determine the number of sensors required, and receive any guidelines or restrictions. Once we receive this information, including details on how to reach the site, we can begin the deployment process. This ensures that we always show the utmost respect for the tribe members and their land.

Another important aspect of deploying sensors in Ohkay Owingeh is being prepared with all the necessary tools to handle various conditions that may arise. In some cases, we may need to adapt our approach and attach sensors to trees or employ unconventional methods that are still reliable in the long term. Therefore, having a comprehensive tool packing list is crucial for successful deployments in Ohkay Owingeh.

Figure 4 illustrates the challenges encountered when deploying sensors in hard-to-reach locations, emphasizing the determination and perseverance required to overcome these obstacles and ensure the sensors are deployed effectively.

Throughout the entire process, we strive to maintain open communication with the tribe, show respect for their traditions and guidelines, and adapt our methods to suit the specific circumstances of Ohkay Owingeh. By collaborating closely with the tribe and being prepared for various deployment scenarios, we can ensure the success of our sensor implementation and contribute to mitigating the impacts of flooding in the community.

DATA MONITORING SYSTEM

The user interface comprises two main components: a restricted-access SQL database and a publicly accessible internet website built using JavaScript. The SQL database serves as the repository for all data collected by the sensor network and allows for high-level data analysis that is not in real-time. On the other hand, the website retrieves the latest data from the database, processes it to a certain extent, and visually presents it in the form of graphs. Real-time transfer of data occurs between the sensors and the database, as well as between the database and the website, resulting in updates on the website approximately every 30 seconds.

Figure 5 provides a graphical representation of the website and offers an explanation of its main components. Additionally, it includes a link to directly access the website for further clarity. The website's homepage showcases access buttons corresponding to each deployment location, where sensors are depicted using different colors representing their specific conditions. For instance, blue indicates sensors that have been functioning uninterrupted for over a week, green represents sensors operational for 48 hours to one week without disconnection, orange shows sensors active for less than 2 hours, and red denotes disconnected sensors. Users can click on the location buttons to access individual sensors within each location, obtaining detailed information about their conditions as well as communication node status.

Figure 4. LEWIS sensors deployment for Ohkay Owingeh in different environments.

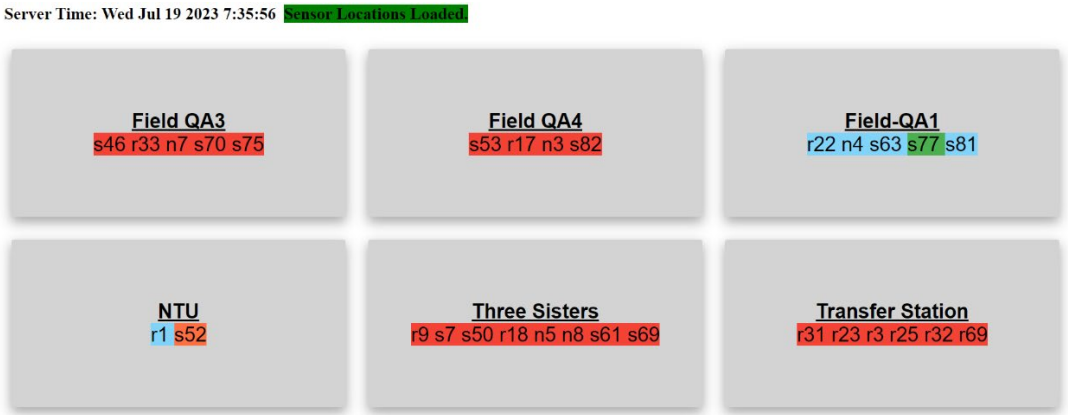

Figure 5. Near real-time sensors' data monitoring system.

CONCLUSION

In conclusion, the LEWIS sonar sensors provide significant value to the community in two key areas. Firstly, they contribute to flood prevention by offering reliable, continuous monitoring across the tribal land. The easily manageable data from these sensors enables real-time flood detection, identification of targeted areas, and assessment of the flood severity. This information empowers the community to take prompt actions to mitigate the impact of flooding.

Secondly, the long-term benefits of the LEWIS sensor data are equally important. Accumulating data over extended periods allows the community to make well-informed decisions regarding the protection of critical infrastructure, improvement of existing buildings, and ensuring transportation safety for its members. By presenting the collected data in an easily understandable manner, the research opens up endless possibilities for the community. The LEWIS design facilitates data collection that has not been available in Ohkay Owingeh before, benefiting the community both in the short and long term.

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