An Open-Source IoT Remote Monitoring System for High-Hazard Dams

Corinne Smith[1], John McCain[2], Austin R.J. Downey[1,3], Jasim Imran[3]
[1]Department of Mechanical Engineering, University of South Carolina, Columbia SC
[2]Dam Safety Program, South Carolina Department of Health and Environmental Control, Columbia SC
[3]Department of Civil and Environmental Engineering, University of South Carolina, Columbia SC

Background

- Dams need to be monitored during severe weather events in case of failure
- Traditional systems are expensive and often permanent
- Solution: open-source electronics can create a flexible, economical alternative

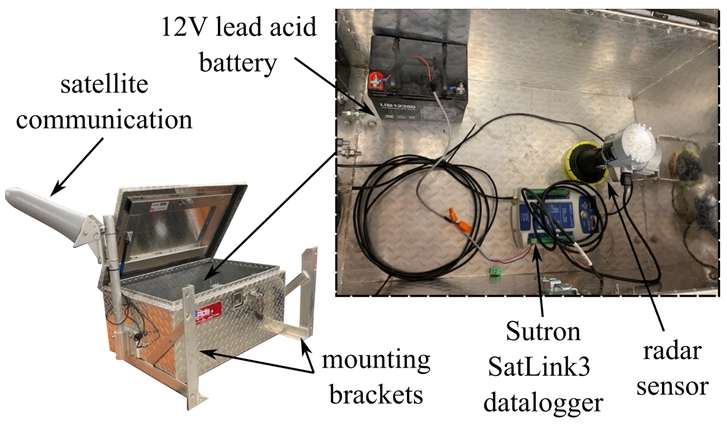

Figure 1. USGS rapid-deployment gage.

Hardware Design

- Based on Arduino Mega microcontroller
- Custom printed circuit boards designed for power management and datalogging
- SIM7000A Botletics cellular shield connects the system to the Internet of Things
- Measures ambient pressure, temperature, battery voltage, and water level

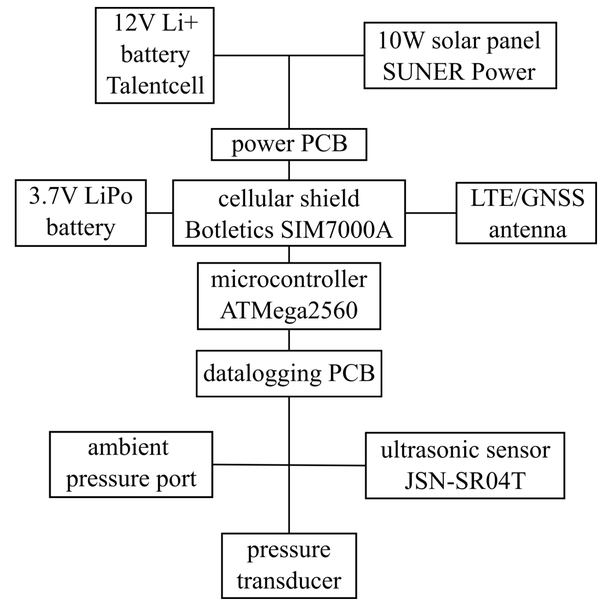

Figure 2. Block diagram of the remote monitoring system hardware.

Filtering

- Noise from ultrasonic sensor would create false triggers
- Different filters were implemented on past data to simulate real-time filtering and evaluate best performance
- Median filter is integrated using edge computing

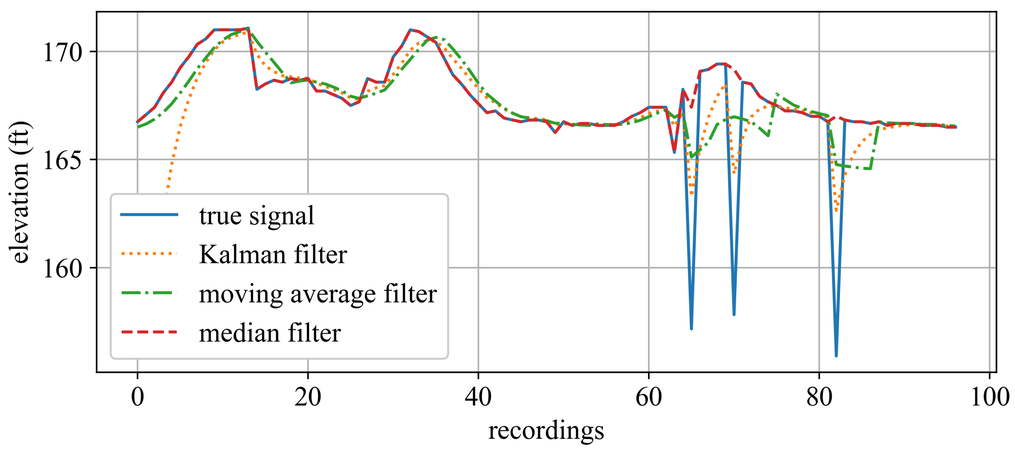

Figure 4. Simulations of different filters applied to ultrasonic sensor data taken on April 5, 2022. Kalman, median, and moving average filters are compared.

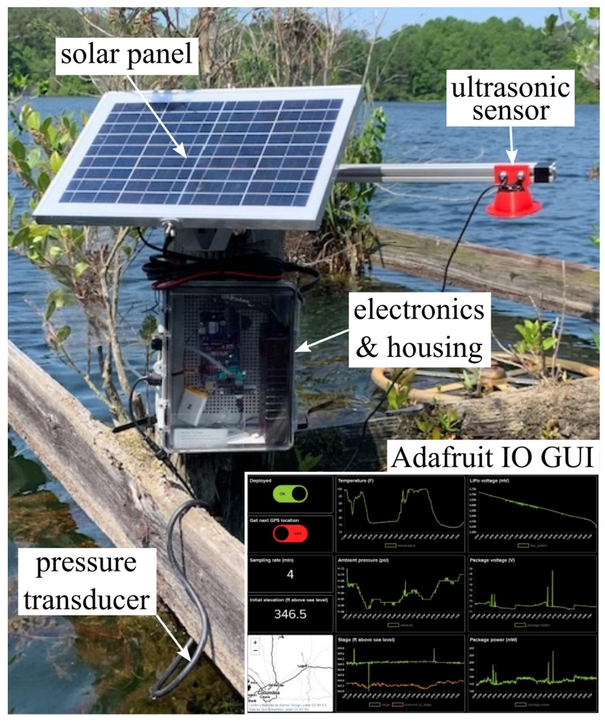

Figure 3. Deployed remote monitoring system on the Sandhills REC Pond Dam's primary spillway showing the custom GUI visualizing data in real time during a deployment.

- Water level measured two ways: contactless ultrasonic sensor and submerged pressure transducer
- 12V Li+ battery pack recharged using a 10 Watt solar panel for power
- Portable, easily accessible, water-resistant housing allows for flexible deployments in severe weather

Data Transmission

- Message queueing telemetry transport (MQTT) protocol is used with Adafruit IO
- Custom GUI shows sensor values as well as sends commands to the remote monitoring system
- Data is sent via LTE CAT-M1 standard for lower transmission rate
- Hologram cellular provider used
- Sensor enters and reawakens from a sleep mode to save power between data collection cycles

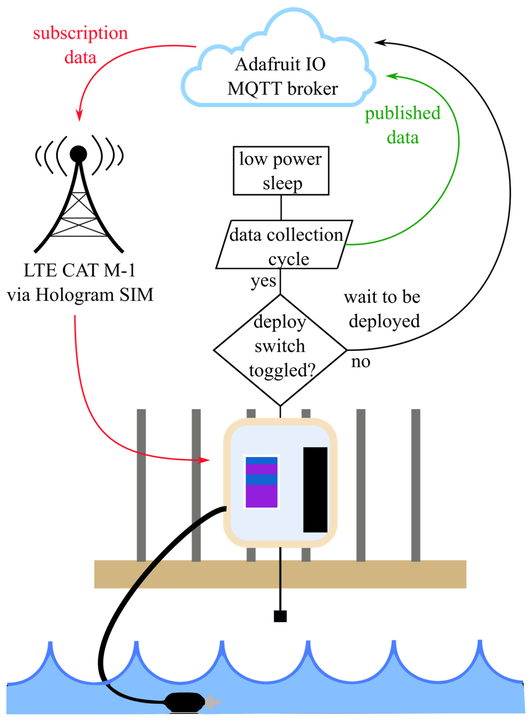

Figure 5. Data collection and transmission cycle.

Experimental Results

- Remote monitoring system is deployed next to USGS gage with HOBO sensor to compare readings
- Ultrasonic sensor follows very closely with USGS gage
- Pressure readings experiences drift, likely due to inexpensive sensor

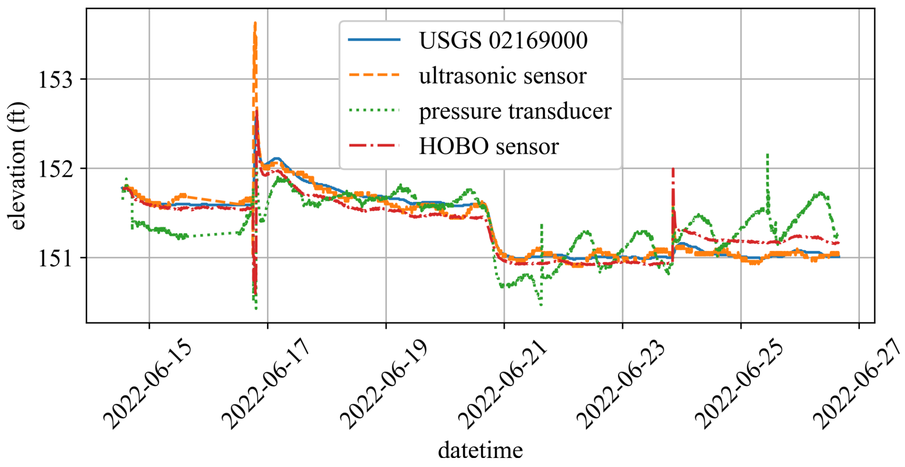

Figure 6. Field test comparing remote monitoring system to USGS gage and HOBO sensor at Saluda Riverwalk, Columbia SC.

Conclusion

- Experimental validation shows the system's accuracy and reliable transmission creates a viable alternative to traditional gages
- Open-source electronics and services facilitate greater technological accessibility for programs with limited budgets
- Further investigation will address pressure sensor accuracy

References

[1] (2022) Dams and reservoirs safety program overview. Online. South Carolina Department of Environmental Control. [Online]. Available: https://scdhec.gov/BOW/dams-reservoirs-safety-program-overview
[2] (2022) South carolina flooding 2015. Online. South Carolina Department of Natural Resources. [Online]. Available: https://dnr.sc.gov/flood2015
[3] Water Resources. (2019, Mar.) Rapid deployment gages (rdgs). Online. United States Geological Survey. [Online]. Available: https://www.usgs.gov/mission-areas/water-resources/science/rapiddeployment-gages-rdgs
[4] V. Sauer and D. Turnipseed, Stage measurement at gaging stations: U.S. Geological Survey Techniques and Methods, 2010. [Online]. Available: https://pubs.usgs.gov/tm/tm3-a7/
[5] C. Smith, P. Lovett, J. McCain, and A. Downey, "Iot cellular dam water level sensor," GitHub, 2022. [Online]. Available: [https://github.com/ARTS-Laboratory/IoT-CellularDam-Water-Level-Sensor]
[6] D. Wolbert. (2022, Mar.) Nb-iot and cat-m1 (lte-m) vs. cat-1: How to choose the right lte iot standard. Online. Hologram. [Online]. Available: https://www.hologram.io/blog/nb-iot-vs-cat-m1-vs-cat-1
[7] U. W. Resources. (2022) Usgs 02169000 saluda river near columbia, sc. Online. United States Geological Survey. [Online]. Available: https://waterdata.usgs.gov/usa/nwis/uv?0216900

GitHub repository