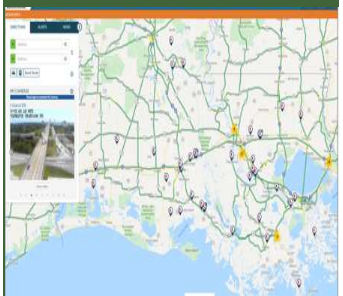
Transportation Consortium of South-Central States (Tran-SET)

Development, Education, and Implementation of a Low-Cost Audio Sensor-based Autonomous Surveillance System for Smart and Connected Transportation Infrastructure Construction and Maintenance

Developing an audio sensor-based autonomous surveillance system for monitoring and maintenance of transportation construction projects



Highlight | Dec. 2020

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Transportation construction and maintenance projects usually entails several miles of job site, and each state DOT is challenged with the daunting task of monitoring progress across all such projects. The importance of an automated monitoring and surveillance system for maintaing transportation construction projects has been long recognized. The objective of this study is to develop a low-cost, wearable, audio sensor-based automated surveillance system capable of faster, more convenient and more accurate work zone monitoring. This system possesses several competitive advantages over traditional site management and existing vision-based work including unlimited range of monitoring angles, no restriction on level of illumination, light-weight data processing, and comparatively quick analytics. This system supports real-time monitoring of construction progress, evaluation of task performance, and rapid identification of safety issues.

Background

The ever growing need for constructing more roads, bridges, tunnels, highways, and others to enhance commute has led the state DOTs to oversee a large number of transportation construction and maintenance projects simultaneously. As such, there is a significant need for a real-time project management and performance monitoring system that can not only help DOT professionals monitor multiple projects simultaneously but also help enhances risk-informed decision-making. Since these projects often span across hundred of miles, the study aims to improve project monitoring and decision making processes by developing a autonomous surveillance system. This system incorporates a low-cost and light-weight audio-based wearable sensor that is capable of automatically relocating while relaying data from a construction field to a cloud-based platform in real-time. Sound-based sensing was adopted in this study as sound is not only light-weight but easier to capture and process as compared to image-based sensing.

Project Summary

The main objective of this study is to develop an autonomous surveillance system that can remotely identify on-going activities at a job site and supervise work progress, emergent situations, working conditions, and safety issues. Specific objectives are: (i) development of a low-cost and light-weight wearable sensor capable of capturing sound-data, GPS locations, ambient conditions such as temperature, air pressure, humity, noise level, etc. in real-time, (ii) development of a deep neural netwrok (DNN) model for accurate identification of on-going activities at the construction site, (iii) integration of a cloud-based platform for real-time streaming, storage, analysis, and visualization of results from various types of data analysis, and (iv) development of a prototype system for real-time monitoring of multiple projects simultaneously through web-based visualization.

The proposed framework was developed using advanced state-of-the-art technologies including low-cost and light-weight sensors that can be worn by a construction crew as a part of their job attire, a deep neural network model for sound classification, cloud-based computing platforms, and web-based visualization. The data flow of the proposed system is depicted in Figure 1.

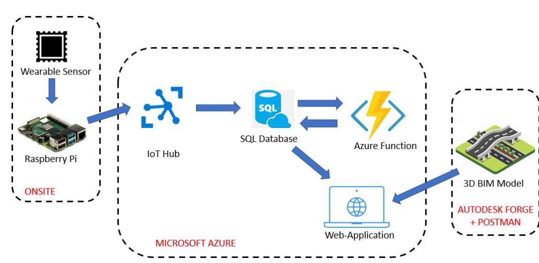

Figure 1. Dataflow of the proposed framework.

Status Update

The sound classification system was trained for a project schedule consisting of 14 work activities. The system was tested under lab settings with both known and unknown data and produced an accuracy of over 90% which was evaluated using F-score and Normalized Confusion Matrix.

A light-weight wearable sensor was developed as an on-site solution for capturing and categorizing sound parameters as well as capturing other ambient conditions such as temperature, air pressure, humidity, noise level, etc. A low power microcontroller unit (MCU) or single board computer (SBC) interfacing with an environmental sensor, GPS sensor and a sound sensor array was used for monitoring the aforementioned parameters. With a Wi-Fi enabled system, this device can constantly stream data to the IoT Device that is capable of relayng telemetry to the IoT Hub. The components of the wearable device developed in this study in shown in Figure 2.

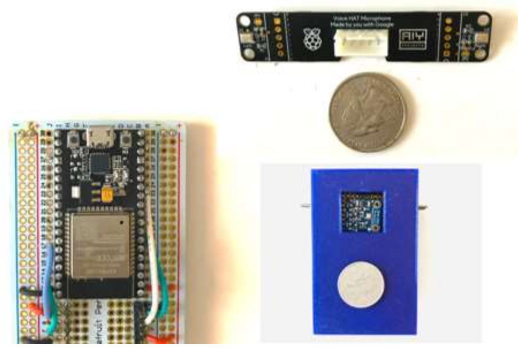

Figure2. Components in the wearable sound sensor-based device

Microsoft Azure was used as the cloud-based platform for collecting, storing, analyzing, and visualizing the data. The Azure platform recognized Raspberry Pi 3.0 as an IoT device and therefore allowed for smooth relay of telemetry data directly into the storage database from where it can be pulled by different Azure functions for various analysis. A web-based application was developed for visualization of the analyzed data with the help of various types of visual graphics, and also allowed for the integration of a BIM model that is hosted as an application on Autodesk Forge with the help of PostMan as shown in Figure 3.

Impacts

The main benefits and impacts of this study are four-fold: (i) the system can be easily adopted by state agencies for remotely monitoring transportation construction and maintenance work zones, (ii) the system can help in accurate work progress evaluation, enhanced construction work/safety surveillance, and leveraged decision-making with an abundant historical work log, (iii) the system provides for a faster, more convenient, and more accurate unmanned site and safety surveillance system, and (iv) the system can help state highway agencies generate long-term project history and

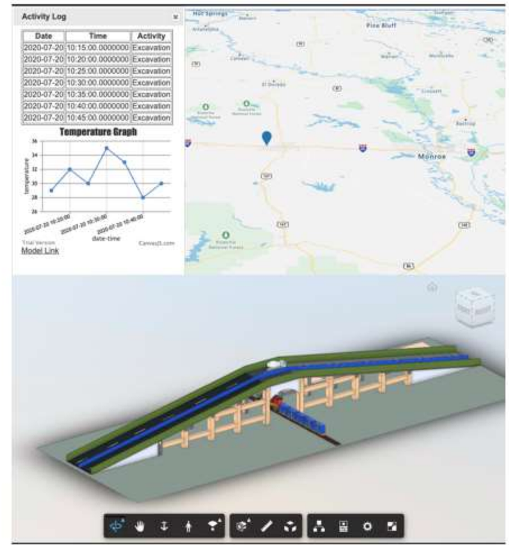

Figure 3. Web-based visualization interface

working log for each transportation construction project.

The outcomes of this research involve new scientific knowledge on the implications of sound recognition and cloud-based platform integration for analysis and visualization in the transportation construction sector for real-time monitoring and forecasting.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.

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