IOT based Concrete Structure Health Monitoring System

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Introduction

Concrete develops cracks overtime when subjected to outside elements and tensile forces. This causes issues to arise from cracks that develop within the structures decreasing the compressive strength of the structure. Using sensor-based readings can aid in determining the health of a concrete structure. A millimeter wave scanner can be used to detect cracks and potential weak points in long stretches of roads. The possibility of products like this are highly likely as they will be cost-effective and more convenient than current solutions. This project will determine the possibility of how this system will function on a small stretch of road.

Background

Concrete is a brittle and weak material under tensile forces. Shown in figure 1 the bending is what creates cracks within the concrete and too large a crack can cause failure [1].

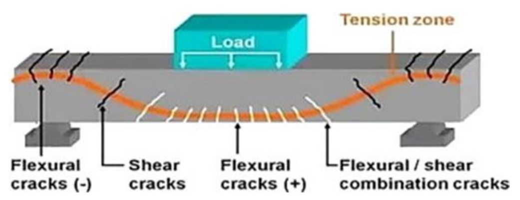

Figure 1 - Causes of concrete cracks and bending stresses

Therefore, most concrete is reinforced to help the concrete become strong in both tensile and compressive forces. It can still crack however and will fail when the cracks are too large. By consistently monitoring methods to fill in or reduce the failure from these cracks can be applied before the crack gets too large and causes a problem with traffic regulation, time, money, safety of the public and vehicles.

Objectives

Detection system (deliverable 1)

- Millimeter wave image system
- Accelerometer to determine crack size/length

IoT integration (deliverable 2)

- IoT cloud can be accessed from anywhere
- Allows for collection and processing of data

Image and alerts (deliverable 3)

- Data from IoT cloud will produce image of crack using contour plots
- Alerts will allow users to see crack location on spot

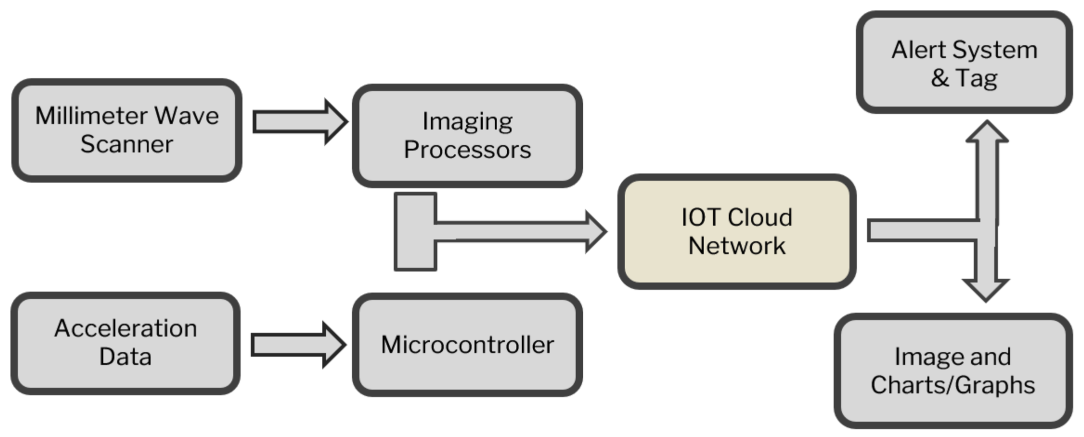

Figure 2 – Flowchart of data handling and processing

Results

The results of different testing methods and display methods are shown in the figures section. Figure 3 shows the first tests and methods of data collection. A rover like toy truck had the sensors attached and would be driven over various cracks. The resulting data provided a contour map from MATLab and excel. The contour map shows a different color depending on the depth allowing for a quick view to give a significant amount of information about the crack. When viewed with the IoT cloud a description of the crack would include the size and a location for the crack.

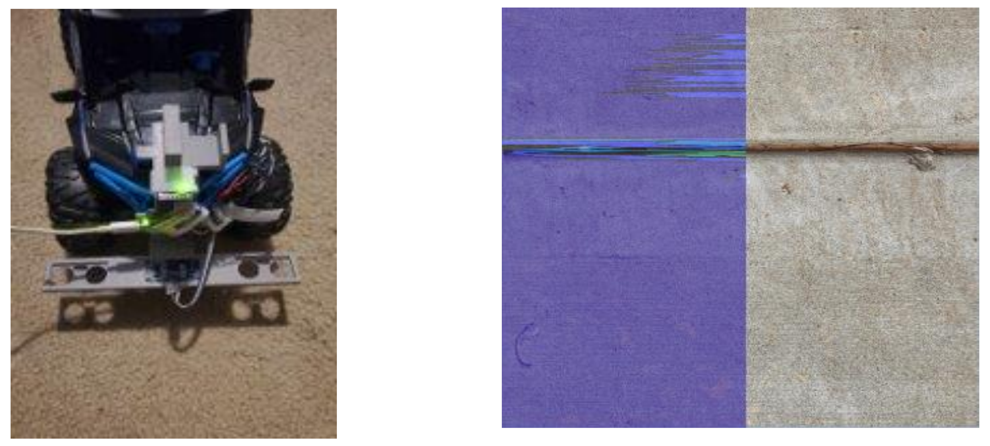

Figure 3 - (Left) First attempts for data collection using a single HC-SR04, Arduino Nano Every, and an MPU-6050 Accelerometer attached by a 3D-printed mounting device to a toy rover truck. (Right) First successful image from testing showing a contour plot overlayed (left-half) on the crack it detected, concrete spacers were a good starting point since a standard distance is used and can be measured and referenced easily.

Figure 4 shows how the same sensor set-up provided similar results when used on a vehicle instead of the toy rover. This stressed the system since the new availability of higher speeds were putting the system to the limit based on the speed of data collection for the precision the system was designed for. Currently a top speed of 50 mph will give centimeter precision of the cracks.

Figure 4 - (Left) Pothole 1 with area and direction scanned indicated with yellow arrow. (Right) Pothole 1 with contour map overlay.

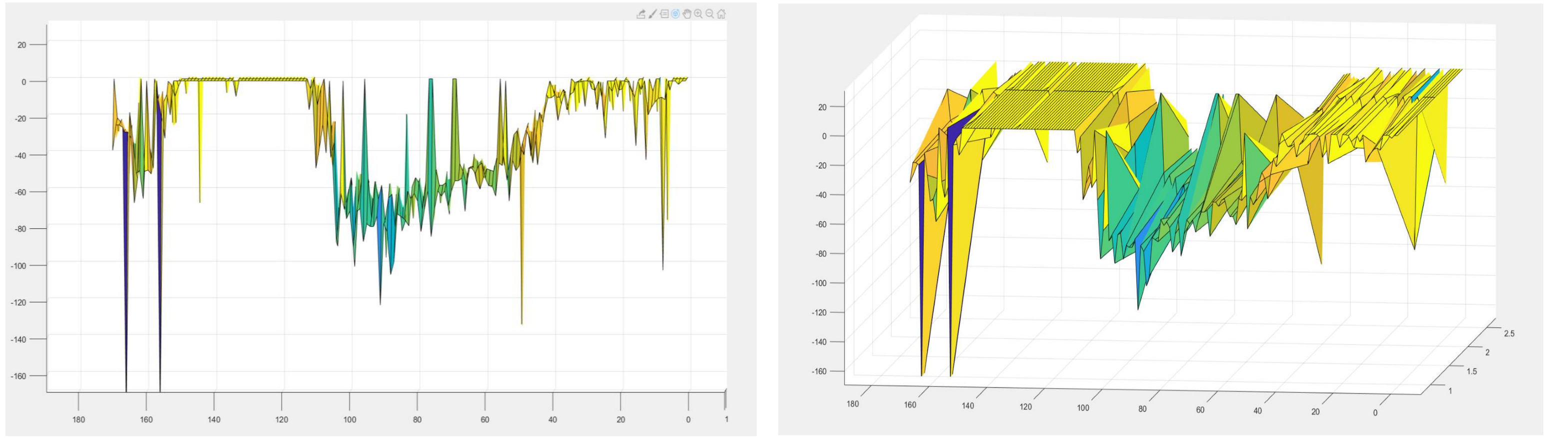

Figure 5 - 3D contour image using HCSR04 on pothole 1

Figure 5 is an extension of the testing from figure 3 where the contour plot was rendered in 3D allowing for better depth detection and monitoring of crack propagation.

Discussion

The concrete health monitoring system used today is the laser. The laser only scans the surface. The expense for laser system can be costly. The IOT system used is too complex. The system designed by the team is easy to mount on a car. The data storage is accessible through the application and can be used anywhere and time. The millimeter wave system is used to not only scan but to measure the dept of the pothole or crack. The simplicity of the concrete health monitoring system is convenient, low-cost and manageable. The system would allow the areas local DoT to monitor crack development and propagation through areas of roads. Using this device will grant large sections of roads to be quickly inspected and increase understanding of cracks propagation speeds. Increasing response times to area with high amounts or large cracks can reduce the occurrence of traffic jams and increase the safety of the roads being driven on every day. Knowing the area of the crack can also aid in knowing how much material should be used to fill/seal the cracks and prevent expansion of the crack area.

Implementation /Conclusions/ Societal Impact

The completion using the ultrasonic sensor HC-SR04 on the rover to detect the cracks. The problem was the accuracy of the cracks and the outliners which did not make sense. Instead of mounting the ultrasonic sensor on the rover we switched to mount it to a car. We successfully were to produce data from cracks and potholes. From the data we successfully produced a plot. The errors were the outliners. We are in the process of fixing these outliners. Also working on millimeter wave system to produce similar data and plot images. Lastly, we are producing the IOT application where it gathers all the accelerometer and millimeter wave data to combine them allowing images to be produced and the area of a crack to be determined. This can be used to monitor crack propagations on sections of road for higher or lower traffic and seeing the impact of temperature in the different seasons on speed of crack propagation. Comparing the size of the cracks to the pavement condition index and the roughness index can aid in creating a road health index that allows roads at a certain condition to be fixed while others are still safe. Through a national database, the conditions of different asphalts under different conditions can help determine which asphalt or concrete is best suited for a new road or future roads to decrease cracking and increase traffic flow and logistics. The system will also be able to determine a difference in longitudinal vs transverse cracks.

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References

[1] G. Ramesh, D. Srinath, D. Ramya, & B.Vamshi Krishna. Repair, rehabilitation and retrofitting of reinforced concrete structures by using non-destructive testing methods. *Materials Today: Proceedings*. **2021**. https://doi.org/10.1016/j.matpr.2021.02.778