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TTT Design Thinkers Packet

Description of Problem

The M-6 freeway is a 20-mile freeway in Grand Rapids, Michigan that spans across Kent and Ottawa Counties. It opened in 2004 and has seen a steady increase in traffic flow since then. However, with an increase in traffic flow comes an increase in the potential for car accidents and collisions. While collisions are commonplace on any road, not all roads have sufficient enough Intelligent Transportation System (ITS) systems to effectively report those car crashes to authorities. The M-6 freeway is one of those roads. Along the entire 20-mile stretch, only 3 CCTV cameras and 3 dynamic message signs (DMS) are installed. In 2019, only 41 of the 304 car crashes on the M-6 freeway had recorded accident information into ATMS. This statistic states that crash awareness on the road is only 13% and shines light on a problem that this number is too low.

An obvious approach to raise this statistic and improve crash awareness on this freeway would be to install more ITS systems along the road such as more CCTV cameras or more DMS. More ITS systems would be an easy solution conceptually because of their validity in current methodology for recognizing crashes and where they occur in real time. However, that approach is very costly in both production, installation, and labor charges. Instead of using the existing methods of surveillance for car collisions and accidents, how can we integrate current transformative technologies innovating the transportation industry and create a more accurate

and efficient way of identifying these occurrences on the road? This plan seeks to answer this question and in doing so provide a detailed yet feasible solution to a simple yet complex problem.

Solution Development

Our group has set out to improve the crash awareness of West Michigan Transportation Operations Center (WMTOC). We are considering the use of sound detection to develop an accurate crash detection method. Using a combination of old and developing technology we can create an accurate Intelligent Transportation System (ITS).

When looking for similar technologies in the literature, the first one found was an invention by Matteo Sammarco and Marcin Detyniecki. This pair invented a sound-based car crash detection device known as Crashzam [1]. The main idea of this article is that the authors developed a technology that identifies crashing sounds as a way of improving road safety. Here, the authors adjusted this technology to recognize sounds of car impact. This technology can run on smartphones, and it classifies the car crash sounds based on time and frequency domain signals. The results of the study hoped to find a way to reduce time it took for assistance to come to the scene of an accident. Additionally, the authors note that they were able to use the technology to make a clear distinction between the car crash sounds and other likely sounds that occurred within a car. The technology is based off not only a time frequency domain model but also a spectrogram of amplitude peaks model. The external concept may be infringing on personal privacy; however, this idea of filtering out noise and only recognizing sounds heard in the scene of a crash is the basis for what our solution hopes to further achieve.

While Crashzam is a valid possible solution to not only detecting more car crashes on the M-6 freeway but actually the occurrence of car crashes anywhere in the world, the concept of the

application brings about an ethical question. Ever since the 9/11 attack in 2001, there has been a massive grey area between the lines of protection by data collection and invasion of privacy. Crashzam's concept of detecting car crashes from inside the car falls in this blurred region and begs the question: is this approach too invasive?

To possibly satisfy those who answer this question with a yes, our transportation technology tournament team, The Design Thinkers, proposes a solution that utilizes sound collection, adaptive noise cancellation, and crash sound detection to alert the stakeholders involved in this problem on the M-6 freeway. These stakeholders are the Michigan law enforcement, fire and rescue, MDOT, and traffic information media. Of course, the Michigan law enforcement and EMS are the first to arrive at the scene of an accident. This means that this solution would help in their efforts to provide care to the citizens of an accident in a much quicker fashion. In terms of the traffic information media, this solution would better get data to them in which they could use to better improve public safety and solutions to everyday problems such as the one given in this report. This proposal is taking the internal concept of Crashzam and planting the sound collection device along the freeway outside of the car. Although Crashzam is practical, it seems insufficient for the public to download an app that is always listening through their cellular devices. Therefore, this solution seeks to be noninvasive of public privacy making it more realistic for implementation.

Our Solution

Our team's proposal solution is to create a smart road that can accurately detect car collisions, collect the location of the accident, and to share that data with other intelligent transportation systems. To create a smart road, we will use the acoustics of the road's environment.

Our solution involves the use of signal isolation using the Fourier transform. Our target signals, or signal, are common to car crashes. These include, but are not limited to, breaking glass, screeching tires, and scraping metal on metal or asphalt. The detection of these sounds along a road is a clear indicator of an accident or car collision. We can also estimate the severity of the accident. The severity of the accident can be estimated by the target sound detected. For example, when only tire screeches are detected, the severity will be lower than when a combination of breaking glass and scraping metals are detected.

Along the 20-mile stretch, we plan to install 5 electret microphones every mile. This ensures that a car going an average speed of 60 miles per hour passes a microphone around every 1000 feet. Hopefully, this would provide safety that is not at the cost of the individual's privacy. Overall, this solution was built around the public's safety and finding a method that would be less invasive and beneficial to the area in which this plan was implemented.

Functional Architecture

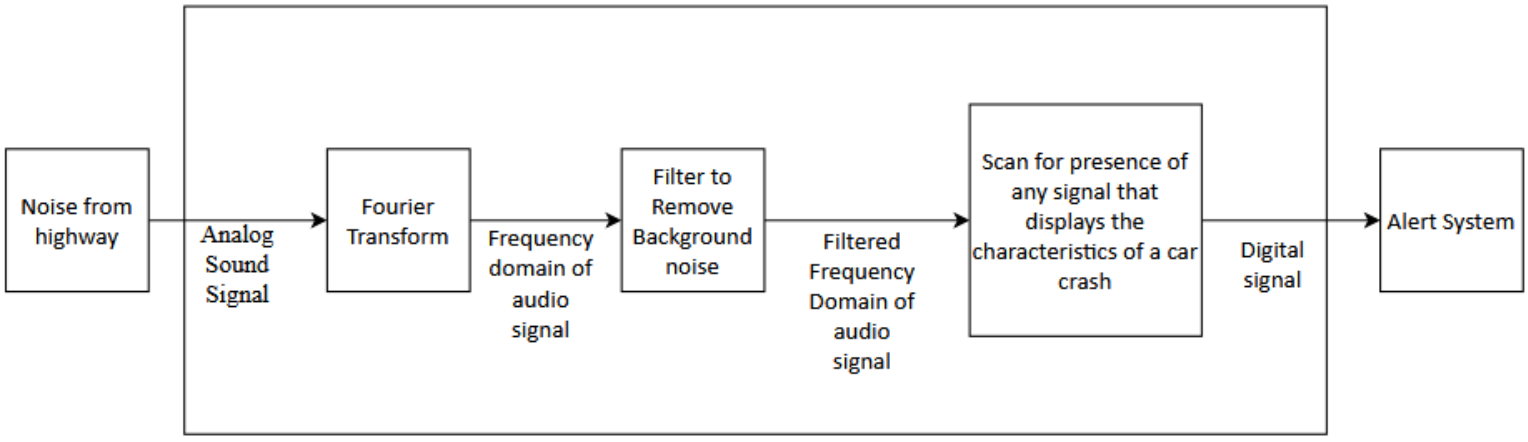

Figure 1 Level One Functional Decomposition

Detecting a Car Accident

Our proposed solution is a system that will take audio recordings and apply signal processing techniques to identify when an accident occurs. This system will involve multiple stations placed along the highway. Each station will take an audio sample and use a Fourier transform to convert the signal from the time domain to the frequency domain. This system will be loaded with the Fourier transform of the audio signal of the typical background noise of the highway at its given location. The system will then use the data it has on the background noise to filter the background noise out of the audio sample using a recursive least squares filter. We plan to use the RLS filter as this system needs to be able to process real time signals. This filtered signal will then be compared to frequency domain signal of known sound associated with automobile wrecks.

When an Accident is Detected

When the comparison finds a match, it will send a signal to activate an alert system for law enforcement, fire and rescue, Michigan Department of Transportation, and West Michigan Transportation Operations Center. The alert system will provide the location, severity, and time of the accident. Once the accident alert system is activated the process will restart. If no match is found the process will restart without sending a signal to the alert system.

Physical Architecture

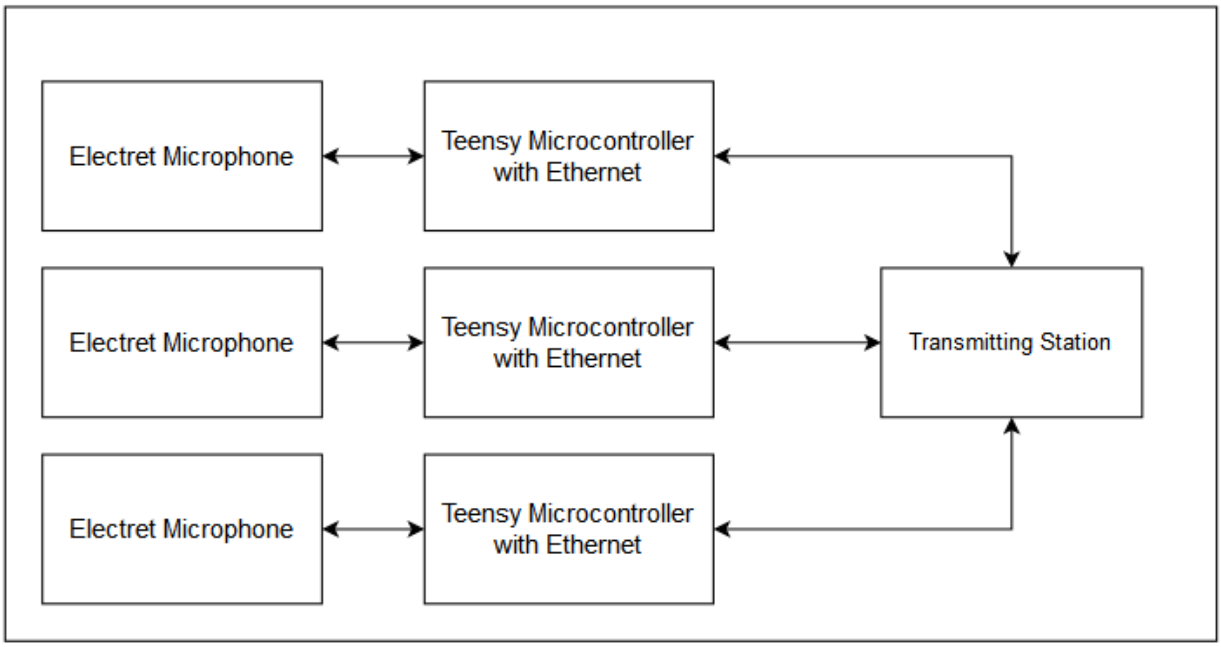

Figure 2 Hardware Diagram

Our system proposes to use several monitoring stations along the highway. Our system would place 5 monitoring stations per mile, or a monitoring station approximately every 1000 ft. We propose to use a Teensy 4.0 microcontroller with an ethernet kit to perform all of the signal processing tasks. We chose to use a Teensy over an Arduino for several reasons, namely the Teensy's faster clock speeds, the ability to connect the teensy using ethernet, and Teensy's SD card slot which would allow us to load data to the Teensy without an additional module. Each monitoring station would also be equipped with one or more electret microphones. These microphones were chosen for their ease of connectivity, lower power draw, wide frequency response, and low cost. Several of these monitoring stations would then be connected to a transmitting station, which would detect when one of the monitoring stations indicates that it has detected a crash and transmit a signal over a directional Wi-Fi antenna to alert first responders.

We chose to use transmitting stations with directional Wi-Fi antennas to help reduce the cost of installation by reducing the amount of cable needed.

Enterprise Architecture

Our team is composed of six members: two electrical engineering undergraduate students, two civil engineering graduate students, a mechanical engineering undergraduate student, and a biomedical engineering undergraduate student. To allocate work assignments we will assign workloads based on each other's strengths and desires.

During the project, we all completed individual research assignments. The two electrical engineering students focused on the sound detection algorithms, the mechanical engineering and biomedical engineering students focused on frequencies of car crashes that would need to be detected, and the two civil engineering students focused on the civil engineering aspects of the project.

To track and manage our project, we will report our progress weekly back to the project manager, along with this we will continuously analyze our progress, so we can adjust our scheduling as needed. Doing this, as well as maintaining a cooperative attitude, will allow us to complete our project in a timely manner. The project direction was decided on by group consensus. All group work was also divided into manageable pieces and members decided on which section they would handle. Within our group each member treats each other member with respect, we also allow for everyone to have their turn to speak and are mindful of our ideological differences. When problems arise, we will step back from the situation so that we are able to resolve differences in a calm and rational manner. This holistic approach to solving problems was pivotal in the success of this group.

Impacts and Risks

With the implementation of this project, the city will notice operational, safety, mobility, and environmental benefits. The use of microphones, opposed to the traditional camera, will improve the efficiency and speed of operations. Currently cameras operate on supervision principles to detect objects or events. The problem arises due to the wide variety of events which can occur on an interstate. Crashes could occur at multiple locations, and it is the role of the supervision system as to whether this crash goes noticed. These unique events will not be detected as accidents. If the crash is not noticed by the camera system, the only other way of notifying authorities is by the bystander who calls the accident in. This is where the use of microphones is advantageous. Sound analyzes and sound detection can be completely automatic. The system does not need human monitoring to detect accidents. If the system does not require humans to detect the crashes, this cuts down on the economic side of crash detection after implementation of this system. With this being said, further improvement of this project could entail camera systems being a secondary measure to this solution; however, this can be developed after integration and trials to verify that this system is successful and impactful. Automation important to build an Integrated Transportation System because this leads to less error in the grander scheme of a design.

The integration of sound detection for crash collisions into other existing systems such as emergency services and traffic information systems can produce many safety benefits. The emergency response to accidents will be increased as the need for bystanders to notify authorities is completely removed. When connecting to emergency services there are a few factors which must be known. Where did the accident occur? When did the accident occur? How bad was the

accident? Through the implementation of our system, we will know which microphone picked up the accident. Therefore, we know the approximate location of the accident. We can also record when the sound was recorded. Lastly, we can approximate the severity of the car collision using sound processing techniques. Future research could be done in this area of approximating severity as a way to let authorities know of how serious the situation they are responding to is.

The same information can be used to prevent car collisions. It is common for multiple vehicle car collisions to occur in low visibility or frozen roads. Using the location of detected accidents, we can notify the West Michigan Transportation Operations Center. They can then take measures to ensure the public knows of extremely dangerous parts of the road. This improvement in communication is very beneficial by not only focusing on the safety of those at the accident but also to those approaching the accident.

Overall, this solution provides improvement of trust between the public and the authorities who would be monitoring for the crashes detected. If implemented, our solution would decrease the time it takes for authorities to be notified of a crash but in doing so allow the citizens that drive everyday on this road to know that if an accident occurred, they would be taken care of. The public should have an understanding that their crash is being detected, and they should feel safer because they know this. The problem given is not just a statistical conundrum. These crashes are not being recorded which means that the authorities never knew about them to begin with and never provided aid. The public's safety should be first in priority in any context. Therefore, this solution has an impact in a social context.

Lastly, there are major environmental benefits. When a car collision or accident goes unnoticed, there is trash left behind. Broken parts such as bumpers, glass, and tires are a common site on long drives. WMTOC is unaware of the trash left behind because they did not know an

accident occurred. With our project we can notify WMTOC of where car collisions occurred. This transfer of information is essential to keep the environment clean.

The main risk in our system is the risk of false alarms. Our project relies on the frequency of car crashes. However, there are many frequencies that are present in any given environment. There must be enough research performed to ensure that we know which frequencies we can expect in the given environment. The frequencies could come from unknown sources such as special vehicles, animals, or even construction sites. These frequencies could cause false alarms in our system. We believe that possible avenues that the project could take are in only measuring the duration of the sudden car crash sound. This could differentiate the car crash noise from the false alarms that are persistent. In other words, the duration of the car crash sound in combination with the filtering of the sound could produce a viable solution to only recognizing the sound of the accident.

Without a doubt, this solution is only theoretical, and the viability of the project can clearly only be impactful if actually implemented and tested to produce actual results. However, the internal concept of noise filtering has been verified in other contexts such as the ones previously researched such as Crashzam. This shows that if truly thought about from all aspects, this plan could show potential in improving crash awareness. Furthermore, improvement of crash awareness goes beyond this single problem, and this means that this solution could be used in other contexts and globally in other transportation areas. The limitations of this project are notable, but this report should provide the basis of for a project that could one day give a better solution to the decreasing crash awareness of this area. This solution has a strong beginning, but it is clear that more research should be done to create a way to better improve crash detection and keeps the public safety as first priority.

References

[1] Sammarco M, Detyniecki M. Crashzam: Sound-based car crash detection. In: VEHITS 2018 - Proceedings of the 4th International Conference on Vehicle Technology and Intelligent Transport Systems. Vols. 2018-March. 2018. doi:10.5220/000662920027003