Carnegie Mellonie University - Africa

Embedded System Final Project Proposal

Title : Road Defect Detection System

Case study: Rwanda

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1. Introduction

Roads and transportation systems play a vital role in fostering economic progress and advancement while also providing significant social advantages. Neglected or poorly maintained roads limit mobility, leading to higher expenses for vehicle operation, increased likelihood of accidents, and the subsequent costs associated with human and property damage. Additionally, inadequate transportation infrastructure exacerbates issues such as isolation, poverty, diminished health, and limited access to education in rural areas[1].

Additionally, poor road conditions, such as potholes, bumps, and surface irregularities, can lead to vehicle damage, increased fuel consumption, and discomfort for drivers and passengers. Currently, there is a delay in repairing such road conditions due to a lack of awareness, approximately in a month time before the in-charge department take decision for repair.

Timely detection and repair of these road defects are crucial for ensuring road safety and minimizing maintenance costs. This research project proposes a comprehensive solution for road defect detection and mapping **using accelerometer and GPS sensor data**[2]**.**

2. PROJECT OBJECTIVES

Main Objective

This project aims to detect the part of the road defected in Rwanda.

Specific objectives

The project is aimed specifically to:

I. Identify the defection in the road.
II. Mapping the defect on road network map
III. Provide insights of road defection to the Ministry of Infrastracture(**MININFRA)**

3. Methodology

The development of a road defect detection system necessitates a comprehensive methodology, blending insights from related literature, correct data gathering from sensors, precise mapping of detected defects, and sophisticated analysis techniques.

To commence this endeavor, a thorough review of pertinent literature will be conducted. This review aims to identify unresolved issues and potential avenues for improvement in road defect detection systems. Utilizing online research methodologies, diverse reports discussing road defect detection will be studied, focusing on aligning findings with the specific case study at hand.

Central to our proposed methodology is the utilization of accelerometer sensors to capture crucial data regarding changes in vehicle acceleration indicative of road defects. These sensors will be strategically mounted on each side of the vehicle, totaling four sensors. By selective changes in acceleration patterns across different sides of the vehicle, instances of road defects can be effectively identified. Notably, data collected from these sensors will be transmitted to the ThingSpeak web application, purposefully designed for IoT projects, facilitating seamless data integration and accessibility via API.

Efficient maintenance necessitates precise defect localization. In this regard, GPS technology emerges as an invaluable tool for accurately mapping detected defects. Integration of GPS functionality into the system will enable the seamless identification of defect locations, empowering maintenance teams to swiftly address identified issues.

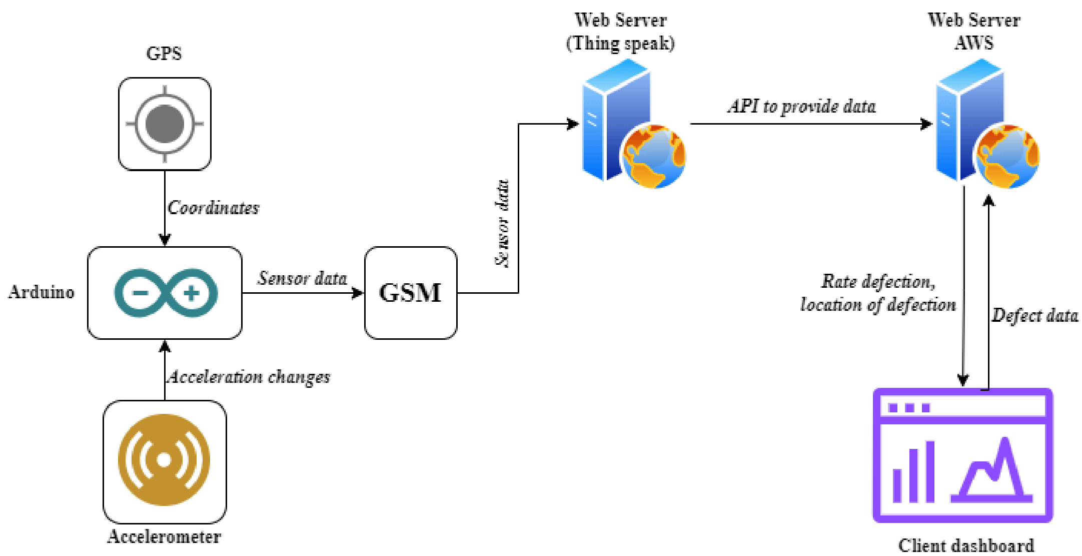
The essence of our methodology lies in the exact analysis of sensor data to derive actionable insights. Leveraging the versatility and computational effectiveness of Python, sensor data will undergo meticulous analysis. Subsequently, ReactJS will be employed to visually represent the analyzed data, facilitating intuitive comprehension and decision-making. Bridging the gap between Python and ReactJS, FastAPI will serve as a robust framework, ensuring seamless integration and communication between the two platforms.

A road defect detection system merges cutting-edge sensor technology, refined data analysis techniques, and advanced visualization methods. By sticking to this systematic approach, we endeavor to enhance road safety, optimize maintenance procedures, and ultimately contribute to the advancement of transportation infrastructure management.

4. Expected outputs

A car equipped with four mounted sensors will capture acceleration fluctuations, transmitting this data to an Arduino microcontroller. The Arduino will interface with both an accelerometer and GPS unit, collating their respective data streams. Subsequently, the GSM module will facilitate the transmission of this combined data to the ThingSpeak server, which offers an Application Programming Interface (API) for integration into our application. This application will engage in data analysis, visualization, and decision-making processes, ultimately delivering insights to the end user via a Dashboard interface.

The following figure shows the connection between each component:



5. List of components

The following is the list of components required to develop this system:

a) **GPS (Global Positioning System)**

The GPS module integrated into the RDD system will serve as the cornerstone for precise geospatial positioning. By continuously providing accurate location coordinates, the GPS module enables the system to pinpoint the exact geographic locations of road defects detected during vehicle traversal.

b) **Arduino Uno Microcontroller**

Central to the functionality of the RDD system, the Arduino Uno microcontroller will orchestrate the integration and processing of sensor data. Interfacing with sensors such as accelerometers and GPS units, the Arduino Uno will collect real-time data on vehicle movement and location. Its programmable nature will allow for the implementation of algorithms to analyze sensor data efficiently.

c) GSM SIM 900 Module

The GSM SIM 900 module will facilitate seamless wireless communication between the RDD system and external servers or platforms. Integrated with the Arduino Uno, this module will enable the transmission of sensor data, including GPS coordinates and accelerometer readings, to remote servers for further analysis and processing.

d) ThingSpeak Server

Serving as the central data repository, the ThingSpeak server will receive, store, and manage the information transmitted by the RDD system. This platform will provide a secure and scalable environment for storing sensor data, facilitating real-time monitoring and analysis of road defects.

e) AWS (Amazon Web Services) Service (Web Server)

Leveraging the capabilities of AWS, a web server will be deployed to host applications that interact with the data collected by the RDD system. This includes a user-friendly dashboard interface for visualizing road defect data and an analytics engine for generating insights from the collected data.

f) Accelerometer

Mounted within the vehicle, accelerometers will detect changes in acceleration indicative of road defects such as potholes or bumps. The data collected by accelerometers, in conjunction with GPS coordinates, will be processed by the Arduino Uno to identify and map road defects in real-time.

Addendum, Milestones

SN	TIME FRAME	ACTIVITIES
1	**1 April - 5 April 2024**	Gather Requirement
2	**15 April - 19 April**	Identify defect and map
3	**22 April - 26 April**	Providing insight

6. Conclusion

The target is to come up with a comprehensive solution able to collect and analyse data for road defection while providing exact geographical location and severity of the defect by leveraging **accelerometer and GPS sensor** data. succesfull implementation of this project will pave the way for further advancements in road condition monitoring and predictive maintenance strategies leading to improved road safety, reduced maintenance costs, and enhanced driving experiences

References

[1] S. Burningham and N. Stankevich, ‘Why road maintenance is important and how to get it done’, 2005.

[2] A. Alrajhi, K. Roy, L. Qingge, and J. Kribs, ‘Detection of Road Condition Defects Using Multiple Sensors and IoT Technology: A Review’, *IEEE Open J. Intell. Transp. Syst.*, vol. 4, pp. 372–392, 2023, doi: 10.1109/OJITS.2023.3237480.