Development of a Smartphone-Based Road Performance Data Collection Tool

tech transfer summary

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A smartphone-based app (CyRoads) and a Raspberry Pi-driven smart box system were developed to help Iowa's local agencies collect pavement roughness data more cost-effectively and frequently.

Background

The International Roughness Index (IRI) is a globally accepted standard for measuring road roughness, defined in terms of the longitudinal profile of a traveled wheelpath. This important parameter affects the ride quality of a vehicle as well as vehicle operating costs and tire wear. Quantifying road roughness helps transportation departments make maintenance and repair decisions.

Problem Statement

Various techniques, such as the use of high-speed and walking profilometers, have been developed to quantify road roughness. While these methods remain essential for many transportation agencies, they are often costly or time-consuming. Smartphone-based tools present a promising opportunity to broaden data collection capabilities and enhance the maintenance of road networks.

Several successful experiments have demonstrated that modern smartphones can effectively collect roughness data, and many commercial mobile applications, such as Roadroid, TotalPave, and RoadBump, have emerged to serve this purpose. However, these applications are not tailored to meet the needs of Iowa county engineers.

Objective

This study aimed to develop a smartphone-based system for collecting pavement roughness data in Iowa.

Research Description

Two tools were developed for gathering a vehicle's vertical acceleration data during pavement surveys: a smartphone-based app (CyRoads) and a Raspberry Pi-driven smart box system. The research team designed a cloud server to interface with both tools for data processing and reporting and developed an advanced Python-based algorithm to convert vertical acceleration into pavement roughness. A control app for the smart box was also developed and tested.

The tools were calibrated for speed, device type, and vehicle type at a standard calibration site. Five speeds were evaluated to develop a speed correction function that allows users to correct or calibrate their devices to improve measurement accuracy.

The tools were then validated for accuracy at 24 roadway sites in Story County, Iowa. The CyRoads app was installed on an iPhone and three Android devices, and the app's performance was compared to that of the smart box and a reference high-speed profiler.
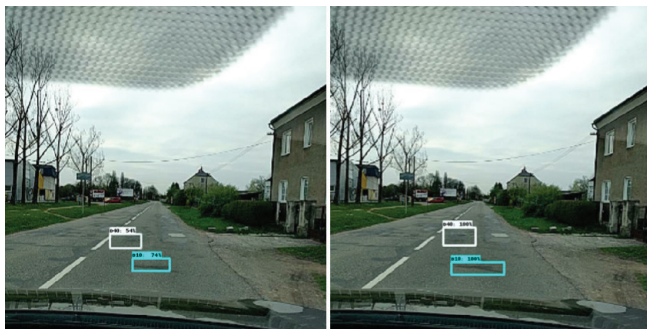
CyRoads smartphone app
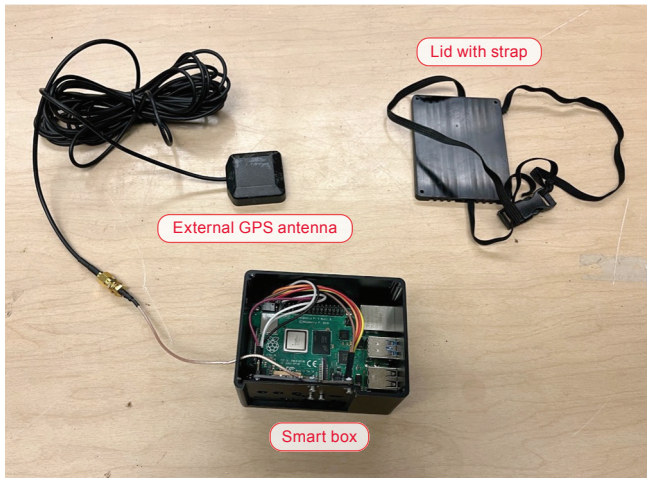
Smart box

Image source: Arya et al. 2020

Smartphone camera images showing the results of automated distress detection (left) versus the ground truth (right)

A prototype smartphone app was also developed and tested to demonstrate the feasibility of using a smartphone-based tool to detect road surface distresses.

Key Findings

- The CyRoads app and the smart box control app are compatible with both Android and iOS platforms and thus the majority of smartphones in use.

- With a component cost totaling approximately $150, the smart box presents a more cost-effective alternative than the smartphone.

- Field tests validated the reliability of the CyRoads app in providing accurate IRI measurements. Results show a line of equality (LOE) R2 ranging from 0.77 to 0.85 and an average percentage difference of less than 13% compared to reference values from a Class 1 high-speed profilometer.

- The smart box achieved an IRI measurement accuracy comparable to that of CyRoads, with an LOE R2 ranging from 0.78 to 0.82 and an average percentage difference of under 13% compared to reference values from a Class 1 high-speed profilometer.

- The speed correction function efficiently and adequately improved measurement accuracy across all smartphone models and the smart box.

- After speed correction, no significant disparities were observed between the measurements gathered by the truck and the mid-size car, indicating the developed tools' potential for uniform measurements.

- The road surface distress detection app proved capable of utilizing deep-learning models to facilitate real-time detection of potholes and cracks through videos and imagery captured by the smartphone's camera.

- The deep-learning models evaluated were chosen due to their minimal latency and superior mean average precision. Adequately trained models were able to identify road defects with a mean average precision of up to 17.04 and a swift image processing duration of merely 40 milliseconds.

- Efforts have been made to integrate the IRI data captured by the smartphone app and the smart box into extant pavement management information systems (PMIS).

Key Recommendations for Implementation and Further Research

- Exploring alternative speed correction methods such as machine learning techniques has the potential to enhance measurement accuracy.

- It is recommended that the developed tools be calibrated and tested with a broader range of vehicles, including vans and sport utility vehicles (SUVs), to ascertain their compatibility with the system.

- There is a need for a robust web-management system that can seamlessly process data uploaded from both smartphones and smart boxes. This system should efficiently categorize the data and establish user authentication protocols.

- The performance of the app and the smart box on granular roads should be evaluated, and correction methods tailored to these roads should be devised based on the findings.

Implementation Readiness and Benefits

The CyRoads app and smart box allow roadway roughness conditions to be surveyed more frequently and cost-effectively, helping Iowa's local agencies promptly identify problematic road segments and make informed maintenance decisions.

The state-of-the-art Python-based algorithm developed in this study for interpreting IRI data offers invaluable insights that can equip Iowa's local agencies with a deeper comprehension of roadway roughness conditions.

The insights and recommendations resulting from this research are expected to pave the way for enhanced measurement precision and efficiency, a broader scope of applications, and seamless alignment with PMIS. These improvements can further enable Iowa's local agencies to adeptly collect data on road conditions and refine their maintenance and rehabilitation strategies.

Reference

Arya, D., H. Maeda, S. K. Ghosh, D. Toshniwal, H. Omata, T. Kashiyama, and Y. Sekimoto. 2020. Global road damage detection: State-of-the-art solutions. 2020 IEEE International Conference on Big Data (Big Data), December 10–13, Virtual Meeting. pp. 5533–5539.