Assessing Road Quality Using Crowdsourced Smartphone Measurements

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Problem

As the demands on the nation's roads increase, so too have road maintenance costs. To meet these challenges, agencies must vigilantly monitor road surface quality to properly apportion resources. Traditional methods of assessing road quality, however, remain costly and time-consuming.

As an alternative, CSHub has developed a crowdsourcing tool in collaboration with the University of Massachusetts Dartmouth. This tool, called the Carbin app, can offer agencies high-quality data at a lower price and in real-time. Carbin is available on the App Store and Google Play and has collected over 250,000 miles of data since 2019.

Approach

We propose, calibrate, and validate a crowdsourced method of estimating road roughness based on the acceleration signals readily recordable by a smartphone mounted within a vehicle. These signals allow us to estimate that road's roughness Power Spectral Density (PSD), which is related to well-known ride quality metrics, such as IRI and waviness number. Using statistical physics, the app can also estimate the dissipated energy within a vehicle's suspension to calculate the impact of road quality on fuel consumption. This impact is significant: in some cases, road quality can contribute to up to 15% of a vehicle's fuel consumption.

Findings

The approach is applied at two scales: the local scale and the state scale. First, the approach was used to measure the roughness of a highway and an inner-city thoroughfare (**Fig. 1a**). These local-scale results were then compared to those of expensive laser-instrumented vehicles (**Figs. 2a and b**).

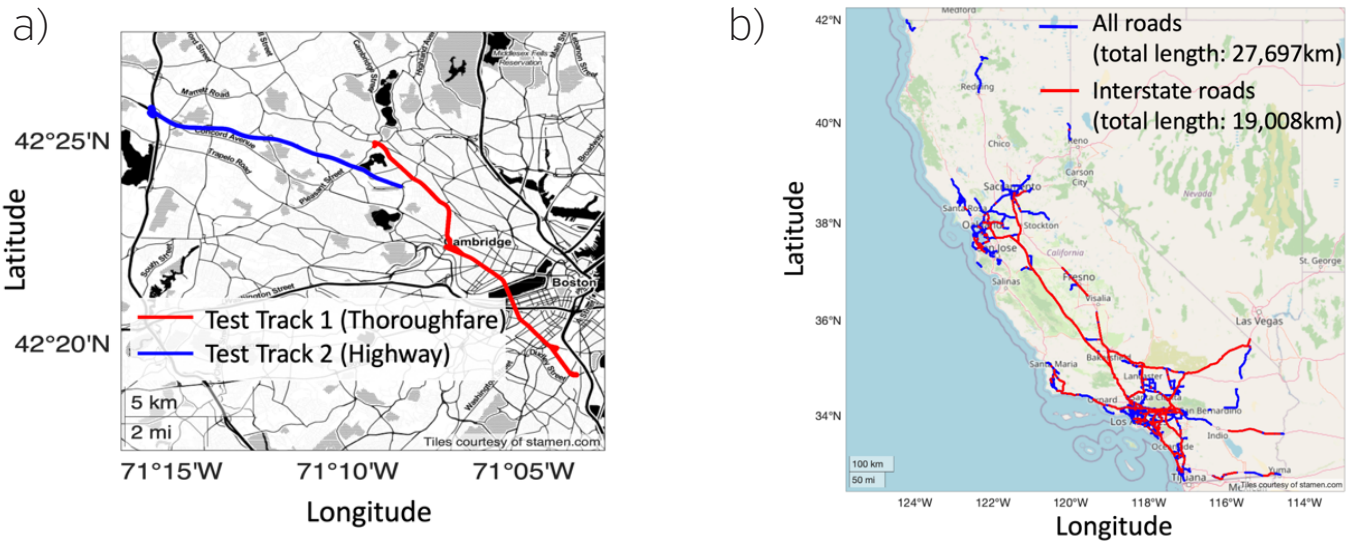

Figure 1: Coordinates of the roads at **a)** local scale, and **b)** state scale (state of California) used to validate the proposed methodology.

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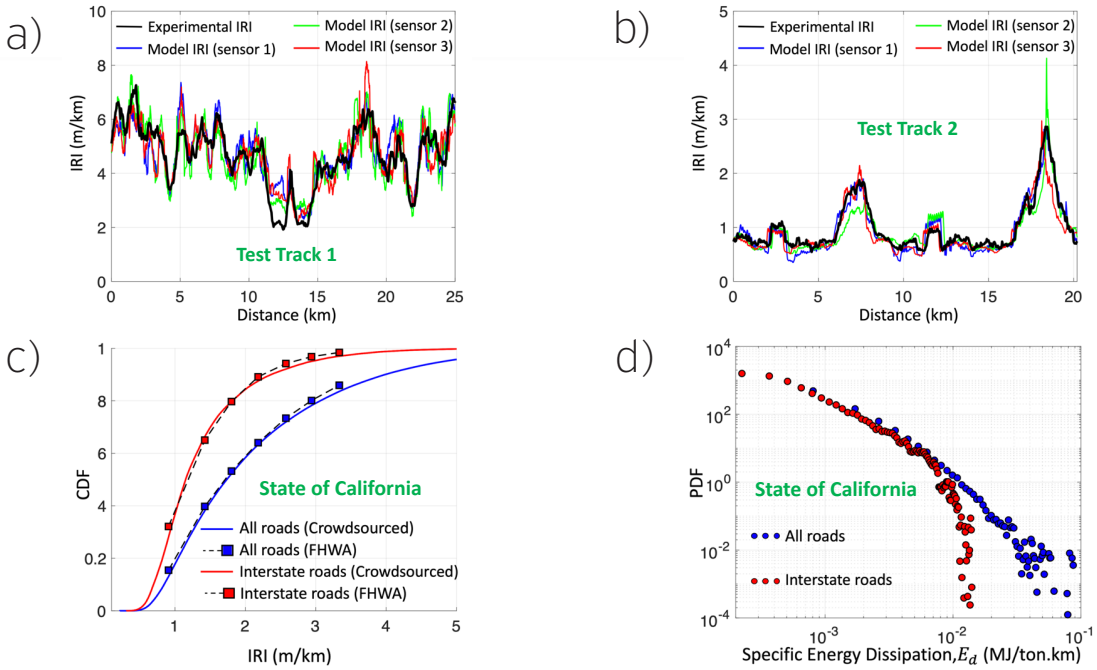

Figure 2: (**a & b**) A comparison between IRI at the local scale obtained from laser measurements (Experimental IRI) and measurements obtained from the proposed approach (Model IRI, sensors 1-3). A comparison of cumulative distribution function (CDF) (**c**) using the crowdsourced data (proposed approach) with FHWA-inferred distribution. The probability distribution function (PDF) of specific energy dissipation for the state of California (**d**): As specific energy dissipation increases, so too does excess fuel consumption.

Second, through a crowdsourced framework, the approach was applied on a state scale to identify the distribution of roughness for the state of California (**Fig. 1b**). Crowdsourced distribution of IRI is compared with the distribution reported by the Federal Highway Administration (FHWA) (**Fig. 2c**). The analyses over both local and global scales show great agreement with the costly conventional methods of roughness identification. Furthermore, the crowdsourced approach can capture the specific energy dissipation, which is an indicator of excess fuel consumption (**Fig. 2d**)—a critical, but often overlooked, criteria for decision-makers.

In the future, this crowdsourced model will incorporate CSHub research to allow agencies to rapidly prioritize road maintenance for optimal network performance, cost, and environmental impacts.

Key Takeaways:

- The proposed method of road roughness identification is, as compared to conventional methods, affordable and easy to use.
- Due to the widespread use of smartphones, such sensing approaches would allow agencies to have access to abundant, up-to-date road quality data.
- This approach could help the road network become more sustainable and economical by improving management decisions.

Related Links:

- Map of Data Collected by Carbin Users

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