Roadroid – Smartphone Road Quality Monitoring

Lars Forsløf

1. Inventor/CEO Roadroid AB, Sweden, Egnahemsgatan 5, 82735 Ljusdal
   mobile no: +46-72-2426620 e-mail: lars.forslof@roadroid.se URL: www.roadroid.se

Abstract

ROADROID’s vision is to create an international road quality standard that helps to make the road quality better and more sustainable in a global perspective.

ROADROID is 1) an “app” to measure road quality, and 2) a website to view road quality. The “app” is designed for Android smart phones. You can easily measure and monitor the road quality and also use the camera for GPS-tagged photos. The app is based on several years of research for the Swedish Road Administration in cooperation with Roadroid inventor and engineers. By a login on ROADROID’s homepage, you can monitor the data and plan, implement and follow up on road maintenance.

ROADROID is correlated with the international standard IRI and can provide the users with a daily picture of the road quality and be a powerful aid in operational follow-ups. It is not a substitute for advanced methods or ocular surveys – but it’s a great compliment. By being able to generate large amounts of data, Roadroid creates statistics that none of the other methods allow.

ROADROID is awarded the Born Global program for globally potential ICT-companies, national nominee for the World Summit Award in Mobile Content, and is competing in “Gallileo masters”.

Keywords: Android, Smartphones, Road Quality, Comfort, IRI, Pavement monitoring

An introduction

The inventor has been working with mobile ITS since 1997, particularly in connection to friction measurements and dynamic intelligent speed adaptation. The original idea for Roadroid came up at the Transportation Research Board in Washington 2001. In a Canadian project monitoring the speed of timber hauling trucks it was simply assumed that where the speed was low –the road quality was poor. The idea of the inventor was to add vibration measurements, and to work more predictively with road damages.

Together with the Royal Institute of Technology, a first pilot was rigged during 2002 and performed during 2003 [4]. We used a high-resolution accelerometer at the rear shaft of a front wheel drive vehicle, connected by cable to a portable Windows PC through a signal conditioner. At that time both GPS and GSM were connected through wired serial connections. Two mechatronic master students built a first prototype using an industrial software system for signal analysis (National Instruments, LabVIEW).
The results were so promising that Swedish National Road Administration financed an R&D project [5] and [6] to further develop and validate the prototype with a focus on gravel roads. During this time, the system was developed into executable C++ software for Windows and the GIS tool Shape-Up was implemented for viewing the road quality in different colours. A thorough validation between ocular inspections and the systems measurements was performed. The results were presented at the Transport forum, Linköping in 2005. 8 segments of 100 m were individually assessed according to 4 classes. Module analysis (experimental analysis of...
oscillation) was performed on a sample of specific sections of the 4 classes. Regression analysis was then performed with rules based on: 1) amplitude levels for different G, 2) RMS (Root Mean Square), 3) The vehicle speed measured and 4) The length in meters. The analysis showed that a single test run would classify properly to 70% compared to an average of ocular inspections, while a single ocular inspection varied more from the average than that. The method was considered objective with a very good repeatability.

![Figure – An example of Validation: Ocular inspection vs. the System](image)

In 2006 the project was finished, and as the inventor got another work the development stalled. The system was considered relatively cheap and simple to operate at the time (~4000 EUR). In retrospect, it had several limitations though; particularly the sensor mounting and cables exposed in the harsh environment under a car, but also the mobile windows 98 computer, the cable-connected and not very accurate GPS, and the low bandwidth GPRS.

**Development 2010-2011**

When the inventor returned to the ITS sector in 2010, the ideas from 2002-2006 were reviewed. A major technical development was the appearance of mobile smartphone platforms. Literally all peripherals that were previously connected by cables were now built into a phone. We knew we had solved some crucial questions 2002-2006, such as the basis for signal analysis and the influence of speed. There were however new big questions to solve, such as:

- Was it possible to pick up the signals in the car coupé? (We knew that different car models would give different signals.)
- Would the lower sampling frequency be enough (100 Hz compared to earlier 512 Hz)?
- Would the accelerometer sensitivity and the G-scale be sufficient (+/-2G)?
- Would different smartphone models return different values (accelerometer sensitivity).

So we started to develop an Android application to start with, and found out how to interpret the built-in accelerometer signal. The choice of Android rather than IPhone was made
considering the open architecture and hardware price/performance relation. When we had the scale of the concept we started to sample data, we drove on different roads with different cars and performed tests using constructed obstacles on a disused airstrip in the summer of 2011.

We drove the tests with several different types of vehicles, such as
- a small pick-up (popular postal/newspaper delivery car)
- a medium/big sedan/station wagon
- a large 4WD, of a type many road inspectors are using

The test track consisted of 5 different obstacles. The test track was passed by each car 5 times each for 6 different speeds: 20, 40, 60, 80, 100 and 120 km/h. Data were sampled with two different units: Samsung GT-i9000 Galaxy S with Android OS 2.3, and Samsung GT-P1000 Galaxy tab with Android OS 2.2.

We sampled both with our algorithm and in raw format accelerometer readings in 100 Hz. This created quite a lot of data to analyze, to bring answers to our questions.
During the tests, we discovered many things:

- There are differences between different car model, especially at low speeds, but also at higher speed. In the 40-80 km/h range, differences are more limited but they still remain. The tests gave us a model for how to calculate the speed influence of the signal for the 3 different types of vehicles earlier mentioned.
- There are big differences between different phones, both for the sampling frequency and the quality of the accelerometer data. It is of great importance to know these dynamics to achieve comparable data.
- It is of great importance to mount the unit correctly, vertically in a good mounting bracket with support both from the wind screen and the dashboard.

Most importantly: the airstrip trials and field trials during the autumn of 2011 really showed that usable data could be delivered. We now had an Android app analysing 100 vibrations per second and saving several essential quality values together with speed and a GPS coordinate! The Road Quality (RQ) was divided into 4 different Road Classes (RC), similar to the original idea (and the presentation in 2005).

Web portal

We now had an application delivering data, but we also needed a viewer, an internet based map tool to present the data. We had dots of quality and coordinates, and we decided to use the Swedish National Road Database (nvdb) as an Open Layer on Google maps and to relate the dots to the nvdb:s road links. Data was zipped in the smartphone and sent by an FTP service to Roadroid’s webserver in the cloud (hosted by Amazon). This operation was performed after finishing measurements and through a Wi-Fi connection. Data files from different Android apps/units ends up on the server directory and in a daily routine they are unzipped and the data placed in a GEO-database for monitoring on the web map.

The four different RQ:s were presented visually with the following legend: **Green** for Good, **Yellow** for OK, **Red** for Poor and **Black** for Bad. On the map we could now first see the dots, and then the dots mapped to the nvdb links. As the single dots are sampled each second, it is hard to get an overview in larger scale and it is therefore much more convenient to use a road geometry. In Sweden, we have from a national perspective used nvdb, since this automatically gives us a lot of powerful features such as road width, speed and traffic volumes. It is however fully possible to use any other geometry (such as Open Street Maps).
The city of Gavle city was first out with a full scale test, using tree measuring units (Smartphones). Gävle City is at the edge of technology and a world leader in utilising GIS. They immediately considered the system as a good aid in the pavement planning. Tests by construction companies in Gävle also state that the system provides valuable information when they need to make calculations to fix a certain road. The summary of information and the possibility to follow development over time is considered unique.

The Roadroid Index

We have done studies of the International Roughness Index and understand the need to relate to this standard. There is however common complaints about IRI, that it is speed dependent and measured in 20 meter lengths hard to scale up and present on maps.

Since a flexible standard for road quality is really missing, Roadroid has from the start thought of how to present data in a comprehensive and scalable way. As previously mentioned, the measuring unit assigns one of 4 road classes (Green –Black) each second. Then we may also for a specific street or stretch of road want to:

- add data from several measurements over time,
- compare results over time in a flexible way,
- automatically generate reports for a street,
- compare with manual measurements,

We want an index that can be used for a small road link, a part of a street, as well as for a long road, a city or a country! The solution is to present the “percentage of each road class” for a stretch of road. This is the Roadroid Index.
Roadroid – Smartphone Road Quality Monitoring

Figure – The scalable Roadroid Index (at left Webtool measurements from Sweroad tests in Cambodia, right autogenerated list of the falling quality of streets in the City of Falun.

Roadroid utilizes the smartphone’s built-in camera, to take GPS-tagged photos (or videos). It can be used during measurements, but also be picked out of the car for capturing details. As required, the web portal will show the photos positioned on the map.

The website also has access to additional quality values (RMS, Peak, IRI) and speed monitoring, all being possible to access as required.

IRI Correlation

We are currently doing studies to correlate Roadroid data, with live IRI-data collected by RST-cars for the Swedish Transport Administration. The setup is to use average values for the road links in the national road database (nvdb) and Roadroids preliminary correlation to IRI is $RC\sim0.9\times IRI+1.8$. It is important to develop this further to integrate with systems as HDM.

Although; - we are measuring different factors - from a different perspective. It exists allot of research of how to measure pavements, surfaces and cracks using multi-million dollar survey cars with lasers, radars, stereo cameras and ultrasonic devices. And it’s a pending discussion of the accuracy and correlation to the real situation, and how to use the input for maintenance and how to relate to and comfort and safety issues.

One problem for us is that the IRI-measurements in Sweden is performed in the summer, and delivered during the autumn. So we have only been able to compare IRI-data from 2011 with Roadroid data from 2012. As the frost heave/thaw is seriously affecting the pavement – as well as maintenance/repaving – it is not a preferable situation.
We have a preliminary IRI-relationship and are currently waiting for the 2012 data as we hopefully should have received until the ITS-World congress. Accept from the high cost for measurements, a limitation is that only parts of the road network is measured every year. Some data is 3-4 years old, while Roadroid immediately delivers the data, and can easily gather data over time.

**Figure – IRI-correlation**

In comparison Roadroid is extremely cost efficient and should be compared with RST, but seen as a great complement to these exact methods. Roadroid can gather big amounts of data over time, make available to see changes from day to day or from months to month. With the Roadroid index it is easy to compare parts of a street, with a road, a region or a whole country. The global internet maps, with the web user tools make it easy to plan and prioritize actions – and to follow up on the results of these! For route planning, road quality data can be integrated in the navigation services for a smooth route planning. Roadroid also creates a unique opportunity for developing countries where advanced methods will not work. As infrastructure and the possibility to travel is an important factor of for growth, healthcare, education and democracy. Financers can be encouraged as they can monitor the situation and results of their efforts visually by internet.

**Acknowledgement(S)**

Many thanks to my two leading wizards, making ideas to reality: Android programming expert, Hans Jones and Web/GIS/database system developer Tommy Niittula.

**References**