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Intelligent Road – Arctic RWIS demonstration platform

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ABSTRACT

Intelligent Road (IR) is a project aiming at increasing safety of the arctic roads in Northern Scandinavia by creating a demo system providing road-users with short-term road weather information. This article presents the IR-system which demonstrates different ways for road users to benefit from the Road Weather Information Systems (RWIS) and Intelligent Transportation Systems (ITS).

The IR-system acquires data from multiple sources and visualizes it for the road users. The data sources are vehicles equipped with on-board sensors and CANbus diagnostics, road weather stations (RWS), open-data services like Digitraffic, weather forecasts and local weather stations, respectively. The data is stored to the system server to be processed and analysed. The demonstration platform uses the data to create a visualization of the current road conditions on the map which is displayed in a web browser interface.

The visualization has to be simple and fast enough for the road users to gain understandable information. As in many other RWIS implementations, colours are used to represent the varying road conditions. In addition road weather forecasts as well as RWS data are visualized. Several algorithms have been developed to optimize the amount of the visualized data, still maintaining good resolution.

A programmable data acquisition (DAQ) system for vehicles, equipped with GPS, GPRS and multiple communication interfaces for practically any sensor, has been developed. The DAQ acquires data from road condition sensors and wirelessly transfers the GPS-stamped data to the IR-server. A road condition classification algorithm, developed by the Luleå University of Technology (LTU), has been implemented in the DAQ software.

A study of C2X-communication between Finnish Meteorological Institute's (FMI) intelligent RWS and by-passing vehicles, both equipped with 802.11p devices, is carried out. The objective of the study is to test the exchange of weather and road condition information. The exchanged data from the by-passing vehicle is used to enhance the accuracy of local weather forecasts. In larger scale, the aim is to deliver real-time data from the IR-system for the weather model development of FMI.

Keywords: Safety, ITS, RWIS, road condition, visualization

1 INTRODUCTION

This article will elaborate on the Intelligent Road demonstration system for road-weather technologies. The basic idea of the system is to combine existing sensors and other technology into a one common system, making it possible to communicate mainly road condition and friction data for the purposes of different road-user segments. The main added value compared to regular road-weather information systems (RWIS) is the usage of in-vehicle sensors and intelligent road-weather stations and linking local weather forecasts and sensor data for improved forecasts and road surface classifications.

The system is created in Intelligent Road project, which is partly financed by the EU (Interreg IV A North programme) along with national co-financers and private financers. The project is a common effort of three main partners; Luleå University of Technology (LTU), Finnish Meteorological Institute (FMI) and Arctic Power (AP) research unit of the Lapland University of Applied Sciences.

The reason why Intelligent Road demo system is established is because slipperiness alone during winter-time is a considerable source of elevated road accident risk, especially in northern countries such as Finland and Sweden [1, 2]. The slipperiness is mostly due to snow, slush or ice on the road surface [3]. Additionally, research shows that drivers often estimate the road friction to be better than what it is in reality even though the accident risk in snowy or icy roads is 4.1 times greater when compared to bare road surface. Moreover, the amount of fatal accidents in conditions with loose snow and slush was calculated to be even 4.9 times greater. [4]

According to our surveys in the Intelligent Road project, 87% of regular non-professional road-users (n = 217) are looking towards having real-time accurate road-weather information at their disposal and 87% of this group was willing to have it while driving. Tourism is a significant industry in the Northern parts of Finland and Sweden. Our questionnaire results show that foreigners, such as tourists, are concerned with the driving and road conditions in the North since they are not accustomed to arctic winter weather. Consequently this segment also sought after real-time road weather information and information on how to adjust their driving. These are just examples of the road-users' needs that vary between segments.

Launching new services that provide real-time road condition information is seen as important in order to help road users in preparing themselves for possible risk factors related to changing road conditions [4]. Our feedback and studies have implications that a comprehensive RWIS tailored for the challenging arctic conditions, has real commercial opportunities. The modern technologies that have evolved around the road-weather are making it increasingly possible to establish valid services for road-users.

2 INTELLIGENT ROAD SYSTEM

The Intelligent Road system described in Figure 1 is a RWIS demonstration platform which consists of several subsystems working independently to measure, process, analyze and exchange real-time data to create useful road condition information for the road users. Each subsystem communicates with the IR main server to deliver and receive latest data. The IR-server is the brains of the whole system as it receives and processes data from different sources and makes it available for road users via multiple interfaces. It also stores all of the data to a database for further use.

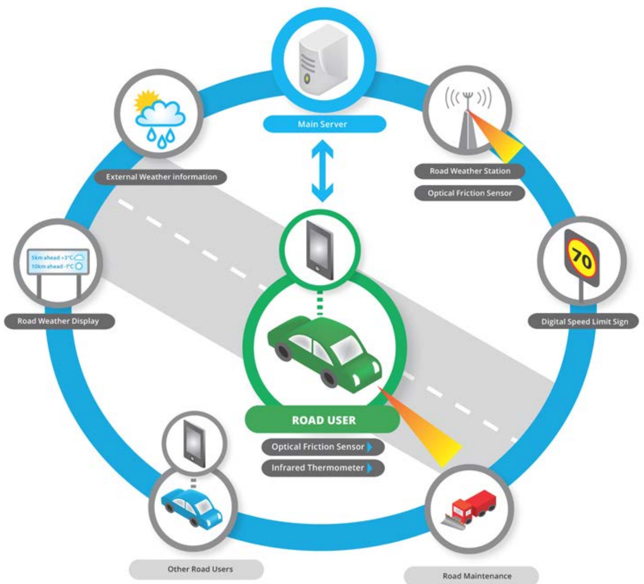

Figure 1. High level description of the Intelligent Road system.

The subsystems include road weather stations, open-data services and vehicles equipped with measurement systems sensors to mention few. The subsystems communicate with the IR-server utilizing GPRS/3G, IEEE

802.11p and other methods. These subsystems are the data providers in the IR-system architecture. They provide road condition, road friction and temperature, road weather and road weather forecast data.

Relevant road condition and weather data is visualized in a web interface using Google Maps API. Different colors are used to display varying road surface and friction conditions. The map view also includes RWS information and road weather forecasts. Data validity depends on time and weather conditions. Oldest data is discarded from the view.

It is possible to interface the IR-system with other services. For example data collected by IR-system can be sent to road side displays and digital speed limit signs to warn and inform road users about current and forecasted road conditions in the road section ahead of them. Also weather forecasts can be improved by IR-system data.

3 INTELLIGENT ROAD IN-VEHICLE DATA ACQUISITION SYSTEM

The in-vehicle data acquisition (DAQ) system developed in the project is designed to collect, process, transmit and receive real-time data from different sensors and data sources as described in Figure 2. It is a python programmable device equipped with multiple interfaces and functionality such as CAN, RS-232, Ethernet, Wi-Fi, XBee, GPRS, GPS and digital I/O. It is also possible to interface other devices to the DAQ to connect analog sensors or IEEE 802.11p devices. Practically any sensor or device can be connected to the DAQ.

The main sensor of the in-vehicle measurement system is the optical road condition sensor. At the moment the DAQ is compatible with two sensor types: Teconer RCM411 and Road Eye. These sensors measure the current road surface condition, friction and surface temperature. This data is acquired in real-time along with GPS-position and timestamp and transferred to the IR-server for further processing. In a case where a connection to the IR-server couldn't be established, the DAQ system has a memory buffer to keep all the data until the connection is available again.

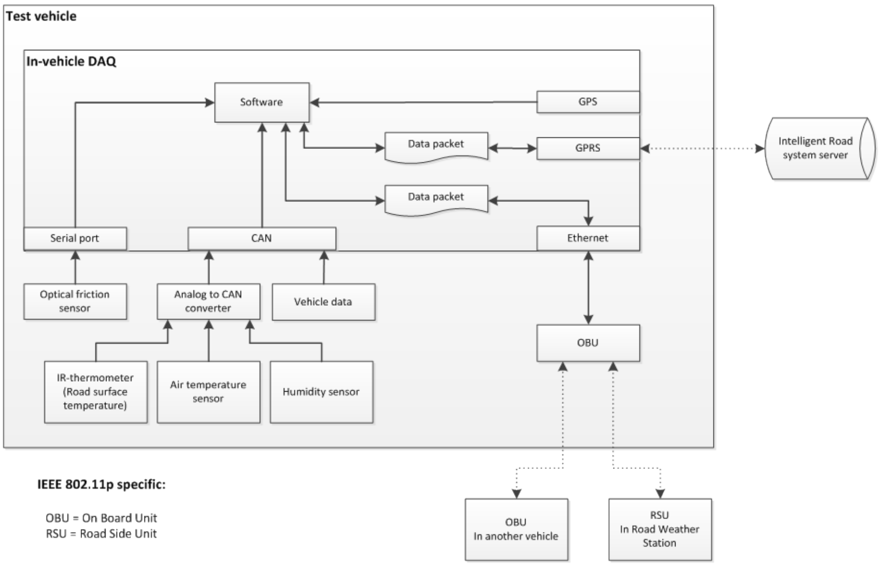

Figure 2. Description of a basic in-vehicle DAQ system setup.

The DAQ monitors the overall system health and sends diagnostic information periodically to the IR-server. The diagnostic information is needed in debugging the system in possible error conditions. Maintenance and updates of the DAQ can also be done remotely over-the-air. This makes it relatively easy to maintain large number of DAQs. Configuration parameters of the DAQ and its software can be updated straight from a desktop computer without going on-site.

Currently there are DAQ systems installed to three Kuljetus Kovalainen Oy delivery trucks and to one LTU and one Luleå Municipality vehicle. The LTU vehicle is equipped with both Road Eye and Teconer sensors. Additionally it has a RT3 tire road friction measurement system (TRF) onboard. LTU vehicle will be used to research, compare and validate the performance of different friction sensors in real conditions. Luleå Municipality will use the system in their maintenance vehicle to compare how visually observed and measured road conditions differ from each other.

Future developments of the DAQ system include the deployment of vehicle CAN interface and IEEE 802.11p communication. This will make it possible to use the current systems to acquire data to further enhance short-term road-weather forecasts (Chapter 7) and to exchange data with intelligent RWS (Chapter 6).

4 THE INTELLIGENT ROAD DATA VISUALIZATION SYSTEM

The Intelligent Road web interface in Figure 3 visualizes the gathered data on a map surface. At the moment all of the data is being visualized on the Google Maps layer in a website which makes it accessible for road users with most of the common mobile and desktop browsers. The data being visualized is real time gathered friction and road surface condition data. When the DAQ system installed on the vehicle sends the data to the server, it is immediately processed and available on the visualization system. Received data is stored into a MySQL database on the server. In addition to road condition information, data from road weather stations in Finland and Sweden is also received. This information can be optionally viewed on the map. FMI is also providing road weather forecast for selected routes (Chapter 7). This forecast is updated twice in hour and becomes available immediately.

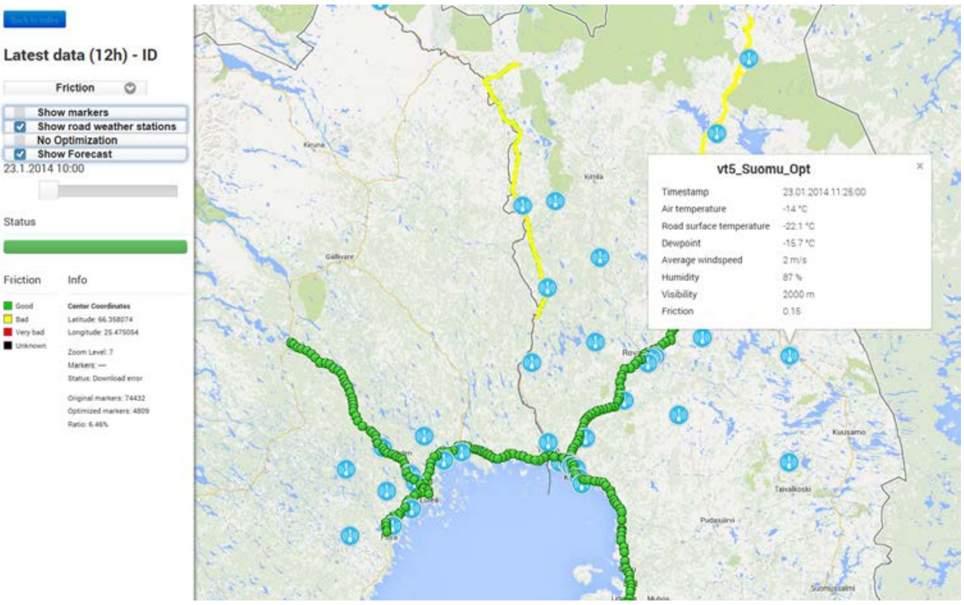

Figure 3. Intelligent Road web interface showing road weather forecast, road friction and RWS data.

Visualizing accurate data from multiple vehicles on geographically large areas has been the most challenging part of creating the data visualization system. Number of data points increases when viewing a larger area which causes the time spent on database queries and plotting the points on the map to increase rapidly. There are also possible memory limitations on the device viewing the website. Currently, web technologies are just not efficient enough when visualizing large data set. Because of this, some optimization techniques have to be used.

Currently, data is optimized based on time, distance and deviation. When the next data node is far enough from the previous data node, far enough from the center of the road or road condition has been changed a new data node will be generated on the map. Otherwise the data node from the original data set will be ignored and all ignored data nodes will be replaced with a single line. This way only the necessary data nodes will be visualized on the map. The data nodes are represented as colored circles as can be seen from Figure 4. On the right side of the Figure 4, optimized data can be seen on the bridge passages. Data validity time is set to visualize only the recently acquired data. When the data is out of the data validity interval, it is discarded from the map view thus reducing the number of possibly false data.

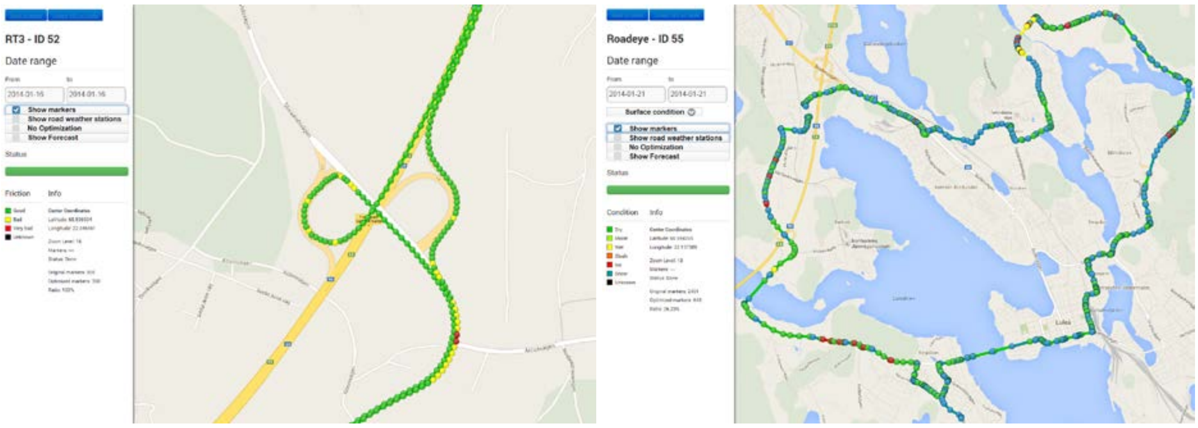

Figure 4. Friction view (RT3) on the left and surface condition view (Road Eye) on the right side.

In Finland the road network data is available as open data from National Land Survey of Finland. This data can be imported into a PostgreSQL database, which has geospatial features added by PostGIS extension. PostGIS and PostgreSQL are open source software. In future the possibility to use this road network GIS data to pre-calculate the road network nodes will be researched. The benefit of this approach is that the road nodes need to be generated only once. This makes it possible to update only the existing nodes instead of calculating new ones every time. Pre-calculated nodes make the visualization faster and more lightweight. An algorithm to map the GPS-position information of received real-time data to match the pre-calculated points is needed in this approach. It will be one of the main future developments of the data visualization system.

5 ALGORITHMS FOR IMPROVED CLASSIFICATION OF ROAD SURFACE CONDITIONS

The Road eye sensor [5, 6] is an optical sensor for road condition monitoring on vehicles. The sensor uses three different laser diodes and a photo detector to measure the reflected light. By exploring the changes of absorption and scattering when the asphalt is covered by snow, ice and water it is possible to distinguish these three road conditions from dry asphalt.

Within the Intelligent Road system an algorithm to estimate the friction of the road has been developed from the road condition algorithm for the Road Eye sensor. The system includes a Halliday Technologies RT3 Curve [7] which is a continuous road friction sensor measuring the friction between a specific studless tire and the road. Installing these two sensors to the same vehicle has given the opportunity to evaluate the Road Eye friction estimation against real friction measurements showing positive results as can be seen in Figure 5.

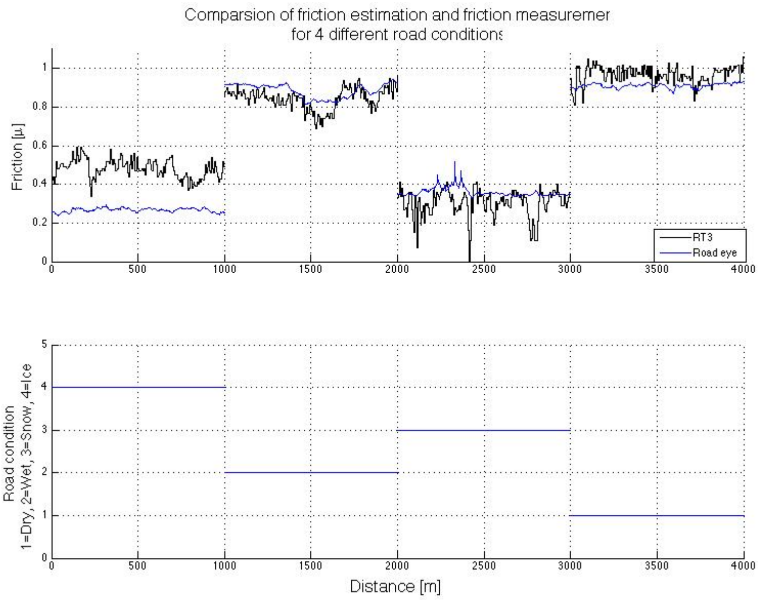

Figure 5. Comparison of friction estimation and friction measurement methods for different road conditions.

Another application developed for the Intelligent Road system using the Road Eye sensor is a road condition forecast based on real-time road condition measurements. There are around 800 road weather stations along Swedish roads. By using the data from these weather stations and the road condition classification from the Road Eye sensor in combination with a local weather forecast an improved road condition forecast has been developed. The road condition forecast has a resolution of around 2 meters if the classification of the road has been carried out. The algorithm takes into account how a dry, snowy, icy or wet road condition will change depending on weather conditions. For example, when the road is wet and the temperature drops below 0°C with some wind blowing, the wet road surface will cool down and turn icy after a certain period of time.

6 INTELLIGENT ROAD-WEATHER STATION

The road weather stations are a common part of the modern road network. Typical road weather station contains temperature measurements from the road surface and air, with wind speed and direction and moisture information, respectively. Many times the station also possesses a road weather camera.

FMI has built a special RWS in Sodankylä for research purposes in order to create new kind of road weather services. This experimental RWS provides the basic road weather station services and additional measurement data not directly related to road weather services. FMI studies the possibilities to provide new services by combining data from the RWS, areal meteorological measurements and large scale meteorological services of FMI. The RWS is presented in the Figure 6 below. In the tower at the right side of the wooden hut the basic RWS measurements are installed, together with two visibility sensors located at the top and at the middle part of the mast, respectively. The mast on the left contains friction and road condition measurements, with optical road surface temperature measurement. Under the road surface, there are road frost measurement systems, going down into 3 meter depth. Finally the wooden control hut contains also wireless communication systems for IEEE 802.11g and IEEE 802.11p communication with vehicles equipped with compatible systems (Chapter 3).

Figure 6. FMI's research road weather station in Sodankylä.

7 SHORT-TERM ROAD-WEATHER FORECASTS

FMI has developed a road weather model to simulate what happens on the road surface due to weather [8]. The model is a one dimensional numerical model that uses numerical weather prediction data and observations as an input data. The model calculates road condition like road surface temperature, state of the road and slipperiness. The model enables route or areal road weather forecasts and the forecasts are updated hourly using the newest observation and numerical weather prediction data.

Road weather stations are installed along the road network to give information about prevailing road condition. The number of road weather stations is about 500 in Finland and most of them are located on most populated areas and on the roads with heaviest traffic. However, those road weather observations are valid only for those points where the stations are located. The information between the stations is missing and it cannot be assumed that the situation would be same all along. Road surface temperature and slipperiness may vary dramatically even within short distances. The local environmental features, like small scale slopes, screening and the vicinity of open water may cause big differences for local road weather and slipperiness [9].

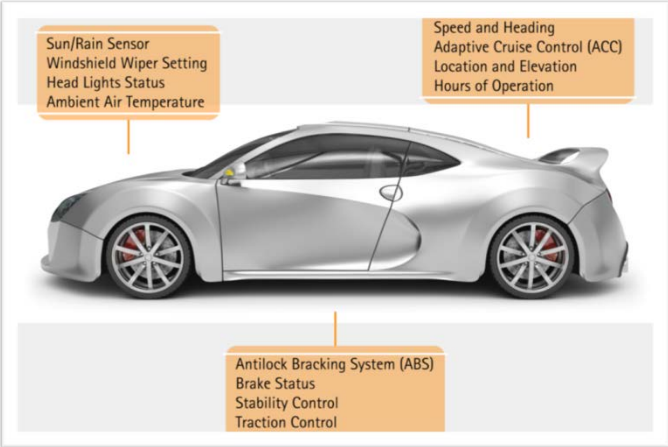

Figure 7. Weather related parameters observed by a vehicle [10].

Modern vehicles are able to measure several weather data and weather related parameters while on the move as demonstrated in Figure 7, and such information can be used as weather observations or additional information [10]. Windshield wipers reveal if it is raining or not, fog lights are detectors of low visibility due to fog, heavy rain or snowfall, ABS and ESP provide information about slipperiness and information about air and road surface temperature can be available as well. The observation can be integrated with GPS data and the gathered localized observation information can be used for several purposes. The information about hazard event, like local slipperiness or very poor visibility, can be sent for other vehicles to forewarn other drivers if such information delivery system available. This kind of C2C and C2I information system was tested and piloted on WiSafeCar project [11]. Also, the information about weather related parameters, including slipperiness, can be used as more detailed initialization information when modeling the predicted road weather.

8 CONCLUSIONS

The added value of the IR demo system compared other RWISs is its functionality as a permanent and expandable platform, where new technologies can be introduced. The system already has different sensors integrated, making it easier to compare and improve them as continuous test data can be acquired from vehicles travelling regularly in the varying arctic road conditions. Currently maintained by a public body, the system is neutral to the technologies. Another added value is that the continuously updated data from the road can be used for improving weather forecasts locally and in road weather forecasts for specific routes. Future developments include the deployment of vehicle CAN and IEEE 802.11p communication enabling C2X-communication and the aforementioned forecast improvements. In the future, using the PostGIS-data and implementing advanced algorithms will optimize the visualization system to handle geographically large data sets efficiently.

In the future, such a system should be maintained with a heavier business-involvement, making it an appealing platform for businesses to test their technologies. The whole value chain should be covered in a comprehensive manner, from sensor developers and manufacturers to final end-users. Such an ecosystem would provide an ideal surrounding for introducing research from various disciplines, allowing the businesses to gain reliable information on the performance of their products in a real-life setting.

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