CENTER OF EXPERTISE FOR THE COOPERATION VEHICLE INFRASTRUCTURE SYSTEMS APPLIED TO ROAD WEATHER INFORMATION FOR MOBILE

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ABSTRACT

Organizations that perform road maintenance provide traffic flow and promote directly or indirectly to the continuity of economic and social activities. The advent of Intelligent Transportation Systems (ITS) now offers new possibilities in terms of information management for improved road maintenance and to communicate with road users.

Transport Canada asked the University of Sherbrooke to propose topics of research in particular Vehicle Infrastructure Cooperation (CVI) applied to mobile Road Weather Information System (RWIS). The objective of this operation is to meet the different needs in information management.

A center of expertise will be developed and projects involving the design of an intelligent vehicle for inspecting the road, the methods of data mining, integration of communication technology P25, treatment of images for recognition of surface and the optimal compression of images are proposed. A first network of researchers has been contacted across Canada and internationally. The potential applications of short-term outcomes is a priority to meet the current needs of various public and private partners.

KEY WORDS

ROAD WEATHER DATA / INTELLIDRIVE^{SM} / CENTER OF EXPERTISE

1. BACKGROUND

IntelliDrive^{SM} technology offers interesting perspectives in Intelligent Transportation Systems (ITS) context to improve traffic flow and safety of Canadian roads. Vehicles are connected to roads or other vehicles, while using the technology of wireless communication. The ITS is important in initiatives related to the field of improving road transportation. Part of this research involves the management of information flow through wireless technology between vehicles and infrastructure, but also between vehicles. A recent term is used to describe this approach: "IntelliDrive^{SM}" which substitute Vehicle-Infrastructure Integration (IVI) (use in the United States on a radio frequency specially dedicated to this type of communication), and Vehicle-Infrastructure Cooperation (CVI) (all types of wireless communication to relay information).

Road Weather Information Systems (RWIS) collect a set of data in real time on the weather and road environment. Sensors are mounted on fixed structures near the roads, or directly on the moving vehicles. Data collected is used to provide information in order to detect or to predict weather events affecting road traffic conditions (presence of ice or snow on roads, dense fog and flooding). Information can then be used to improve the deployment of resources for road maintenance and traffic management, deliver messages to road users. These applications make even more effective management of emergency and warn drivers of some dangers in specific locations on the road network.

The United States, with an agreement between the National Center for Atmospheric Research (NCAR) and the Federal Highway Administration (FHWA) has worked on the concept of intelligent meteorology based on a process based on fuzzy logic since 2000 [1]. The Department of Transportation of Indiana developed tools for real-time information with sensors and GPS to detect the distribution of de-icing materials, and the temperature of the road surface, using a network of wireless communication across the state (Safe-T) [2]. Another example of mobile RWIS technology where is used is in the State University of Montana. They use different types of sensor for measuring the pavement surface temperature, the salinity and freezing, and for detecting ice on the road [3].

The actual equipment can, because of sensors in the road environment, monitor road conditions and improve forecasting of parameters to take into account in decisions. For example, concerning de-icing salts, it is increasingly easy to meet the four requirements set out in the best management practices for salt [4]: application of the right materials, at the right place, at the right time and in right quantity.

Road agencies use more sensors mounted on fleets of vehicles to collect data related to road weather (air temperature, humidity, temperature of the road surface or friction level of the road) and related to operational activities. With the ever-presence of Brake Assistance System (or other technologies as Enhanced Traction System) in recent cars, it is quite possible to assess and record the level of adherence of road user vehicles. It is easy to think that the advent of IntelliDrive^{SM} technology (data communication between vehicles or between vehicles and infrastructure) will soon provide information on operational activities undertaken and in progress, as well as pavement condition and slipperiness. Mobile RWIS will certainly provide good perspectives to improve road maintenance and safety for road users.

Some countries have used RWIS for twenty years to collect weather data near roads of importance. The drawn information is managed to provide optimum conditions for the traffic flow and safety of road users. These systems consist of towers equipped with a sensor set on the roadside. Some road agencies such as the Ministry of Transportation of Quebec, uses mobile RWIS (sensors and data logger on-board vehicle monitoring).

2. SCOPE OF THE PROJECT: STATE OF KNOWLEDGE ON THE WEATHER AND INTELLIDRIVE^{SM} TECHNOLOGY

2.1. The public safety and road weather

Transport on road is an essential component of life for most people around the world. There is always a need to move from home to workplace, school, market, or to another location. There is also a need to use the road network to deliver goods and services, especially in the context where trade exchange is becoming increasingly abundant and without boundaries. It is crucial that all these movements are undertaken safely regardless of the weather and pavement conditions. Unfortunately, the roads are dangerous. They kill and they hurt because of various reasons related to drivers, vehicles, pavement conditions, road signs and weather. In North America, we have recorded several thousands of collisions per year and thousands of injuries and deaths due to accidents. These alarming statistics challenge both the authorities and road users. It is therefore imperative to create the conditions needed to improve road safety substantially.

Bad weather events, especially during the winter, have a dramatic impact on road safety and on time travel. Winter is characterized by the presence of snow and ice formation on road surface, but also by storms and high winds. Countries that are seriously affected by these conditions are required to invest significantly in forecasting weather, pavement condition monitoring and maintenance of road network to allow safe travel while reducing delays. The annual costs to maintain roads during winter is approximately $ 10 billion worldwide [5]. It is colossal, but it's nothing compared to the benefits that can be drawn. These benefits are estimated at eight times the investment costs, which mean that for every dollar spent you save about eight dollars. These costs and benefits vary from country to country depending on the severity of the winter, type of roads, and traffic flow. For example, 40% of annual global spending in winter maintenance are made only in North America.

Canada annually spends several million dollars for safety on its roads. It is a wintry country by excellence, with a long and harsh winter. It is a very big country in terms of area (2nd in the world), which extends from coast to coast. It is also a country with a very dense road network, almost entirely subjected to the inconstancy of winter and it has a very large fleet. Roads are important in trade between Canada and the United States (the largest between two countries in the world). Winter maintenance is a major issue in Canada, more than anywhere else. It is therefore essential to develop the best possible solutions to control the process.

In scientific terms, weather forecasts give a major challenge especially during the winter. The medium and long terms are not reliable. The interaction between changes of weather and pavement conditions was not necessarily well understood until now [6]. The roads are characterized by situations of microclimates due to the variation in land, the presence or absence of vegetation cover more or less dense, the presence of streams, etc. This local variability affects road conditions and challenges data collection systems from fixed stations. In the current context of climate changes, variability in driving conditions become more uncertain and difficult to master. Better assimilation of meteorological, environmental (topography, forests, etc.) data and knowledge of road network characteristics are needed to better predict pavement conditions.

Over the years, many technical developments have been made. The global positioning system records positions in real time, enabling monitoring along the roads. However, the identification of surface conditions, from active or passive sensors is still problematic. The surface conditions in question are the wet or dry asphalt, dry or compact snow, slush, dry or wet ice. Many systems have been developed to measure the temperature between other surfaces by thermal radiometry. The difficulty in having thermal measurements used is mainly related cloud conditions. When cloud cover is high, the temperature of the sky, air and surface are almost identical. It becomes difficult to distinguish state of the surface in these conditions. The use of microwaves is also a challenge. Passive microwave offers great potential, but portable radiometers were not available and very little work has been done on it. Basically all techniques currently used have their limitations in terms of portability, cost and efficiency to differentiate adequately the states of pavement surface.

2.1. State of knowledge of CVI and the mobile road weather information system

The first major projects on the development of RWIS were initiated in Europe in the early 80s. Until the early 90s, few scientific literatures on the subject in the United States and Canada were available. The reason is that the research was primarily conducted by government agencies and the results were used internally. The research report Boselly III [7] provides a concise concept of RWIS [8]. This system included:

- weather sensors to measure air temperature, relative humidity, speed and wind direction, and precipitation;
- sensors to measure the condition of the road : pavement surface temperature, temperature under the road, surface conditions (dry, moist, wet, frost, snow, ice etc..), and amount of chemicals on the road (road salt);
- temperature profiles along the road, based on the thermal radiometry;
- the weather forecast and other relevant meteorological data;
- communication and processing systems, and distribution of information device.

The drawing-up of a complex system requires financial and technological resources. Standardization of measurement instruments and observation methods has given problems since 1994 [9], that is recognized by the Commission on the instruments and methods for observing (commission of the World Meteorological Organization).

The RWIS is a combination of technologies, models, advanced processing and information distribution systems. Taking advantage of progress in these fields since the late '80s, major initiatives launched in Europe, Japan, the United States and Canada provide more meaningful results. Kuennen [10] present a synthesis of key U.S. initiatives (Clarus, Aurora, Clear Roads, etc..). The Aurora program, created in 1996, includes the transport agency of several U.S. states, Sweden and some Canadian provinces like Quebec and Ontario, in order to conduct joint research in road weather [11].

A website (http://www.calccit.org/itsdecision/) summarizes the available systems in several U.S. states, such as that of Washington. The Canadian provinces are also very active with RWIS use (Buchanan and Gwartz [12]). COOPERS (Co-operative networks for intelligent road safety), SAFESPOT (cooperative vehicles and infrastructure for road safety) and IVSS (intelligent vehicle safety systems) are major initiatives in Europe on intelligent transport systems [13] (http:/ / www.safespot-eu.org/). In the 90s, the concept of RWIS was fundamentally based on collecting current weather data and characteristics of pavement from fixed stations distributed along roads (Boselly et al. [7], Gustavson [14]). As for technological advances in telecommunications and the important role played by the automobile industry in the process, the concept has evolved rapidly toward the CVI IVI. This way called "intelligent transportation" implies a two-way transmission through a communication wireless network to provide information from vehicle to vehicle and from vehicle to infrastructure (Petty et al. [6]). How winter conditions being taken into account in such a framework of integration and cooperation?

Works on the weather related road network, especially those on the winter maintenance, concerns all countries with severe climates which affect the condition of roads and transport system. Winter events give situations where decisions must be taken about treatments to provide good road conditions (snow removal, chemical use on slippery surfaces, road closures, etc..). It also requires special attention in terms of driving. It is highly preferable for the driver to notice ice on roads. Providing this conditions requires conventional meteorological measurements, but also data to characterize the condition of roads along the route.

Over the four seasons and especially during the winter, the variations of weather and surface conditions that have impacts on roads, are very random. Under these conditions, road weather stations give important information. The possibility of measurement system in vehicles, able of transmitting his position and weather data collected, is an major asset. Road weather stations provide information at a road network point but do not give information about the road condition between two stations (Bogren et al., 2008). In the United States, the FHWA initiated the development of a road maintenance decision support system. The prototype developed uses current weather observations and numerical weather prediction models to forecast road conditions over a deadline of 48 hours. The current version uses the Metro model, a model of energy balance designed by Environment Canada [6]. Development of a similar system was introduced to Japan in 2004 and produced a prototype in 2005 [15]. Other examples from various European countries like Switzerland, Sweden, Russia and Denmark, were presented at the International Conference SIRWEC in Prague in 2008 (www.sirwec.cz).

3. DESCRIPTION OF PROJECTS RESEARCH FROM THE CENTER OF EXPERTISE

3.1. General considerations

Using various elements summarized above, the Center of Expertise is based on an approach of multidisciplinary applied research. The research areas include several sectors related to the process of collection, transmission, processing and use of data (see Figure 1):

- data collection,
- data transmission,
- data– storage,
- decision support system,
- management support system,
- distribution of information.

For all these research areas, ranges were defined to correspond to the activities of the Center of Expertise and the current needs of potential partners.

Monitoring road weather: the tasks are to validate the forecasts with different sources of observation and to anticipate road weather phenomena. We consider here any relevant information to get a better representation of parameters that are involved in the road weather phenomena.

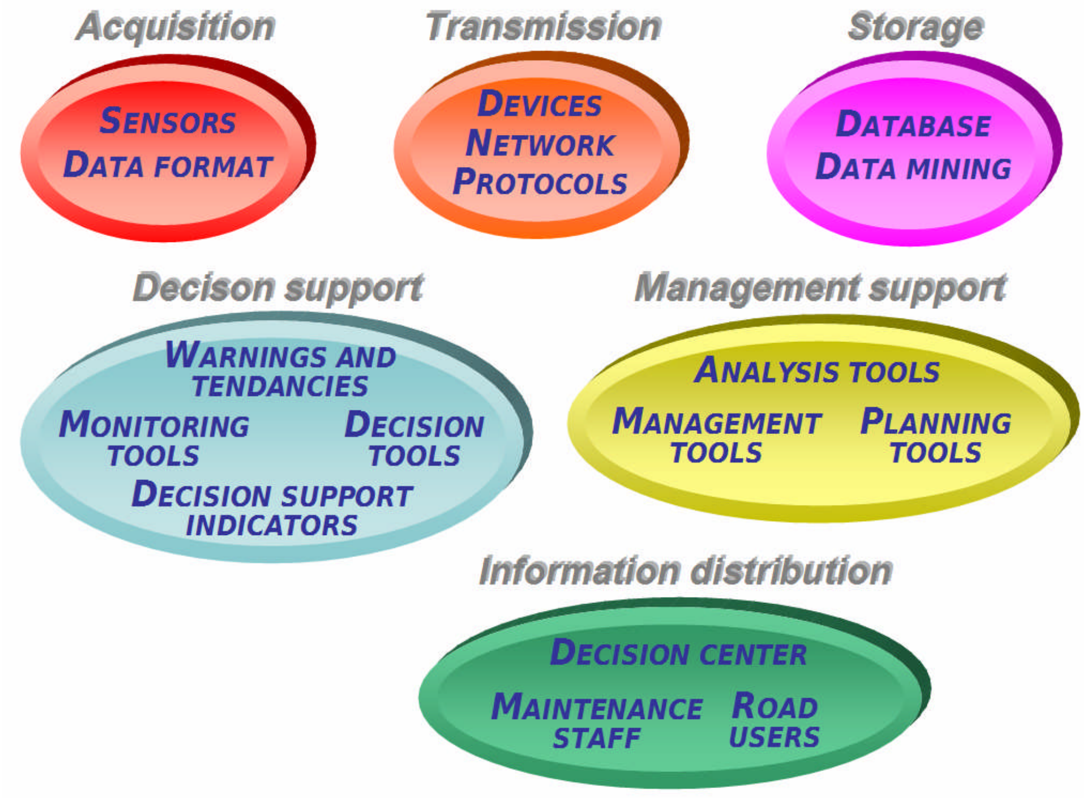

Figure 1 : Center of expertise components

Road maintenance: this includes the various interventions on the road network to provide good traffic conditions in winter (winter maintenance), the maintenance and renewal of signaling elements (signs, traffic lights) and the completion of marking (markings). This scope includes planning, implementation and monitoring of operations aspects.

Monitoring the road network: these activities help us to be aware of abnormalities on a road network and generate action to take temporary measures to correct the situation or make improvements. These include information related to reversed signs, damaged guardrails, sections of slippery road or not cleared of snow, etc.. The management of complaints or requests for service made by road users fall into this range, as well as the decisions of road closure and redirection of traffic.

Emergency management: This scope includes activities that are related to crisis management for occasional weather events that have an impact in the field of transport, or all information relevant to the maintenance of essential services such as health services, fire and police services, in particular traffic conditions due to the weather.

The driver information: This section also covers the whole process of acquisition, transmission and management of road information-weather but which is specifically dedicated to road users, especially the driver. To this extent, the support management refers to the ability to manage information without affecting the safe operation of the vehicle. Distribution of information includes the concern of delivering a message clearly and effectively. We intend to integrate in this scope a project on user perceptions of the whole process of information exchange vehicle to vehicle. The scope corresponds to the axis of Social Research at the Center of Expertise.

3.2. Detection and modeling of road surface conditions during winter

The project focuses on state roads during the winter. It has two components. The first part focuses on the use of a radiometry multi-spectral integrated to determine the various possible states of the roads during the winter season. We assess, respectively:

- detection by passive microwave,
- detection by infrared thermal probing wavelengths yet little used, but with a very high potential
- detection by hyper-spectral radiometry.

The second component of the project focuses on modeling the surface condition of roads during the winter by integrating information extracted by radiometric, meteorological information and data on the physical environment to monitor dynamically the evolution of surface conditions.

3.3. Design of sensor networks for wireless management of roads

This project aims to use wireless sensors to capture and transmit information from the floor, such as temperature, humidity or images. The sensors are arranged and distributed appropriately to form a network of wireless sensors (NWS), which is actually a particular ad hoc network. The information taken by the sensors in a NWS can be sent to multiple types of destination, such as CDC (Center for Decision and Control), DM (decision maker and running mobile), SB (scoreboard). A CDC receives and analyzes information received from the NWS, decides to take action and send a DM and/or a SB. A DM receives information from the NWS from which it may decide to take action, he also receives shares of CDC decided and executed. A SB displays information derived from the CDC, among others, information received from the NWS. We will focus more particularly to image sensors (cameras), where challenges are facing constraints on energy consumption. An application of particular interest is the management of roads in winter conditions.

3.4. Design vehicular wireless sensors

This project aims to determine all possibilities for the development of solutions using information from sensors, combining them with new communication technologies. The goal is to improve weather monitoring and road maintenance and to provide information to passengers for their safety. To do this, data collected by appropriate sensors must be processed locally and communicated adequately to both drivers and management centers for information fusion with other data or to generate actions.

The project has three main components: data collection, communication and treatment. These three components are necessary to reap the potential of sensors. The data is first sampled by the sensors, which can be passive or active devices. Measurements are filtered and processed locally, then sent to the drivers that may correct their driving. They are transmitted by wireless to other vehicles or to a Central for monitoring and control. We propose a new type of research that lies at the intersection of advanced data sensors in vehicles and communication technologies. We will use theoretical and practical approaches to achieve the research objectives.

3.5. Storage and data mining

The work of this theme concerning the mining of historical data related to winter maintenance operations. It's also concerning development of models for classification and prediction to assist winter maintenance operators to make better decisions. Data for winter maintenance operations are from multiple sources (climate data, historical road conditions sent to the media, consumption of materials spread, measurements collected by road weather information systems, activity data from vehicle maintenance, etc. .) of various types (numeric, categorical, structured and unstructured text, sequence, etc.) and including a very large volume. The goal of data mining is to seek and identify patterns in data that represent information that would not have been identified by a human operator or by research programs that are based on general knowledge of the area. Using these patterns from data mining are important to better understand the relationship between road conditions and events/incidents related to transport, and also to develop systems of classification and prediction which are better adapted to the specific needs of a region (an operator).

3.6. Videographic remote sensing and acoustic road conditions

Road conditions in connection with the weather elements are often difficult to predict. The sensors developed for the detection of some conditions appear generally expensive and of limited reliability. This project proposes to use inexpensive sensor with flexible use, to develop an innovative approach to extract combined (acoustic and videographic) information in real time on the road surface and driving conditions. Video cameras installed on roads currently which are under utilized, will be used. The use of embedded video cameras will also be tested and the acoustic properties of tire/road contact will be explored to identify signatures specific to different road conditions. The combination and the performance of these different approaches will be evaluated and scenarios will be put into action at the provincial and national levels will be established.
The project will help train highly qualified personnel (three students and one graduate research assistant) by researchers from the sub-team. It will benefit from the collaboration of international experts. The project will contribute to positioning Canada in the forefront in terms of expertise in detection and transmission of road conditions for users.

3.7. Traffic information governance support system

Weather events can have an impact on the road or on the visibility and increase the risk of road accident or hinder the flow of traffic. The project is to propose methods for processing data from different sources to provide relevant information to road users or decision makers who are responsible for road maintenance. By allowing to follow the tendancies of the road weather, and generating alarms to critical levels, the road user can adapt his driving and reduce the risk of accidents. Data processing will be done by using such techniques in data integration, but also will need an elaborate analysis. The advantage of this approach is to optimize the use of data already existing within organizations and enable traffic to improve returns on recent investments in the field of intelligent transportation systems. To do this, we propose a solution from the systemic approach based on spatial data to support managers in their decision making on road-weather operations.

3.8. Development of a dynamic mapping system on the WEB

The management of road maintenance is complex to achieve because of the difficulty of assessing the impact of road-weather events, depending on their intensity or their geographical distribution. Moreover, data related to resource management are numerous and difficult to integrate into a common application. Data processing and the potential of geomatics offer interesting perspectives, but within the limits of reliability and relevance of data input.

In seeking to provide indicators and architecture of the visual presentation through the development of a model database, the project aims to create a mapping system on the

Intranet web part (for managers: ex. Team maintenance) and Internet (for the audience: former. information to road users). This system will allow you to view on a map the spatial and temporal distribution of selected information and indicators. The development of the system will focus on new tools of representation and transfer of spatial data on the WEB and FLASH technology-Flex for the webcast.

Research results will also lead to recommendations concerning the acquisition of certain types of data in order to make more functional tools to assist management.

3.9. P25 platform for developing advanced applications

This applied research project is developing a radio platform compliant P25. This platform enables communication of digital data and voice communications. A type of this infrastructure called RENIR began to serve all departments and agencies in Quebec. It will allow the field demonstration of a software application adapted to the winter issue of sustainability of the Ministry of Transport of Quebec. Exploring radio techniques performed by software, the platform will be open and extensible. Following its development, it will become the heart of many other projects of the Center of Expertise. It enables the cognitive radio research and computing applied to intelligent transportation systems.

3.10. Experimentation with the use of road weather data on-line

This project aims to determine types of information delivered to the road user which will allow to the users to have a safer driving depending of road weather events. Drawing on different types of professional drivers, the study will focus on the perception of drivers concerning the reliability and the relevance of information and the level of satisfaction.

3.11. Impact of a mobile road weather information system on driving simulated situations

The road weather data can provide useful information to people who drive all sorts of vehicles. This project aims to develop an interface that will be placed in vehicles which provide road weather information. The interface will then be tested for ease of use, taking into account that the addition of vehicle information in the future may affect the primary task of driving. The results of the project will develop a prototype of road weather information system while giving the tags on the optimal conditions for its use.

4. CONCLUSION

The intelligent transport systems are increasingly a part of the reality of road travel. Taking into account road weather events has become essential for better management of road maintenance, and information for road users. In this context, the vehicle-infrastructure cooperation has been developing for several years in the United States. This area of research and applications, that now bears the name of IntelliDrive^{SM}, is growing and Canada has demonstrated its intention to participate to this approach.

The establishment of the future Center of Expertise on ITS is particularly oriented to mobile road weather information systems. The consideration of several axes of research has identified many projects for which targets have been adjusted for faster specific applications and with client partners participation. By a state of the art for each application domains, researchers have established links with several research partners and thus expand a contacts network across Quebec, Canada and at international scale.

This initiative is entirely open to the entire scientific community, is multidisciplinary and in close collaboration with users of mobile road weather information systems to respond adequately and quickly as possible to their expectations. The Expertise Center wants to participate to the development of ITS in Canada and to share knowledge in this field in North America and around the World.

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