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AWIS: an Airport Winter Information System

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ABSTRACT

Even though airports characteristics differ from the environment of roadways, they have several key points in common. For this reason the concept of an Airport Weather Information System is quite similar to a Road Winter Information System. In fact, the problems connected to the difficulties during the winter period on the airport runways consider the following parameters :

- user safety
- runway accessibility (delays, closure)
- corrosion of maintenance vehicles, aircrafts and runway surfaces due to treatment with de-icing substances
- forecast of the surface conditions in order to organize maintenance activities just in time
- higher reliability of the control process of the surface of the runway
- higher trust of users in the control authorities

Therefore, the objectives of an AWIS are various and contribute to a higher safety level of the airport especially during winter emergencies and result in an improved image of the airport reliability. But an Airport Winter Information System can strongly improve all the aspects of the management of the winter events, such as weather reports, control of the pavements conditions, field condition assessments, passenger's safety, and global air traffic efficiency. All these aspects will be verified at the Turin international airport. The final AWIS packet will be the studio of a prototype system to be used in any airport.

Keywords: airport safety, Artificial Neural Networks, weather nowcasting, numerical series forecasting, ice sensors.

1. INTRODUCTION

The concept of a Road Winter Information System is a well known approach which provides a synergy of solutions and strategies for road management, especially during winter season. The same concepts well suit to an airport. Winter is usually the worst period of the year both for roads and airports traffic. Weather forecast systems try to do their best to prevent major troubles. However, more extreme winter conditions can sometimes blow in unexpectedly, as was the case in 2005-2006 winter, when sudden, heavy snowfall disrupted operations at every Italian airport for several hours. As a result, all the airports were closed to incoming traffic and many passengers had to spend the night at the airports. Similar problems occur on the roads. Several countries are trying to organize a Road Weather Information Systems (RWIS). This approach try to put together information dealing with weather forecast, precipitations nowcasting, data of the road conditions, traffic, de-icing techniques, data both for maintenance people and for users and so on. The problem is as much important in the airport case. But today no Airport Winter Information System (AWIS) is available. Every airport tries to auto organize a weather forecast system, using some weather forecast provider, gives out by contract the snow removal service, tries to use the best de-icing products that the local winter "expert" knows and so on. When an extreme severe winter condition occurs this empirical, un-scientific approach shows all its limits. Inconveniences for passengers, lost time and money, sometimes the problems propagate to other airports for a sort of domino effect. A good AWIS could be the right approach to improve the safety and the comfort of the winter events not only in the Turin airport but also in other national and international airports that decide to adopt this method. More specifically an AWIS examines the following points:

• Comparison of road surface condition sensors under various conditions such as snow, ice, wet and low temperature;
• Analysis of different methods for microclimate weather and road surface conditions nowcasting based on these sensorial data, especially for critical event forecasting;
• Optimization of preventive maintenance strategies, such as spreading of de-icing substances;
• Distribution of these data to the airport administration and clients by means of modern communication networks.
• Optimization of the utilization of resources such as human resources and maintenance vehicles.

Next section will examine a general overview of the research project. Section 3 will deal with the techniques we think to use to monitor the weather and forecast the events. Section 4 deals more specifically with the approach we think to use to "nowcast" the weather in the airport area. Section 5 presents some special sensors to be installed in the airport to improve the weather monitoring. Last section presents some considerations about the AWIS project and its future developments.

2. The AWIS project

The aim of the project is to create a synergy among the different aspects of the airport winter safety. Therefore we organized different activities dealing with nine main topics.

1. ***Weather station***: This item is related to a meteorological weather station network for the measurement of local and global parameters. These stations provide surroundings meteo data to a data collection center, which stores them in database together information coming from other sources, e.g. satellites, meteorological radars, NOAA. These data, together with the synoptic ones and the local meteorological radar, are used in the nowcasting system.

2. ***Surface condition sensors on the runway***: This part comprises a set of special sensors, which are able to monitor the runway conditions. They are:

   1. Ice sensors, which provide information on the surface conditions (dry, wet, ice)
   2. Contactless surface temperature sensors, installed on airport maintenance vehicles.These can monitor the surface temperature of the runway even where no dedicated sensor is installed. The data are transmitted to the collection and processing center, which creates a temperature map of the runway.

3. ***Nowcasting system (microclimate short-term weather forecasting):*** This is a software which analyzes the previously mentioned information and provides a short term forecasting (nowcasting) of the runway conditions. It is based on a sophisticated data-mining algorithm and is able to forecast (up to 24 hours in advance) the evolution of the main meteorological parameters and the possible occurrence of critical conditions such as snow, ice and fog.

4. Radar monitoring system: This is a small low cost radar (x band based) designed to monitor atmosphere in a restricted area (30 km) surrounding the airport. The acquired data, having a space-time high resolution, are integrated with those used by the neural nets to forecast precipitation phenomena.

5. Intelligent Electronic spreader controls (ESC): It is an Electronic Spreader Control (ESC) system for the de-icing spreader, able to gather information from the sensors installed on the vehicle and the surface condition sensors. This data will be analyzed and, together with the current position of the vehicle (coming from a GPS receiver), the parameters can be dynamically adjusted in order to improve the result of the de-icing spreading. At the same time the information are transmitted to the central station. This enables the central processing station to gather the complete conditions of the runway.

6. ***Slippery control on board of the de-icing spreaders:*** This is a slippery sensor and it is installed on the spreaders. The knowledge of the slipperiness of the runway, especially at the contact between the wheel and the surface, allows the spreader to adjust the quantity of de-icing substances. A model of the revealed values and an identification of the surface condition will be developed.

7. ***Runway database:*** This database is based on experimental data of fields tests. These items will allow a detailed description of functional performance of the runway pavement.

8. ***Optimized materials (anti-icing chemical and wearing course mixture):*** Here we analyze the results of the tests carried out in laboratory and supplemented by full-size test sections; investigations will allow the optimization of the anti-icing treatment technique. Further tests will also focus on the development of innovative solutions for the construction of wearing courses.

9. ***Pavement thermal model:*** This element is a thermal pavement model and it will be available as a predictive tool to detect critical conditions for ice formation and it will integrate the information obtained from the other components (sensors and predictive algorithms).

Awis provide also an informative aspect. A special web monitor will be available to give all the information about the Turin airport in next hours to passengers. But also agencies (ENAC) which control air traffic will use these data to improve their information.

3. WEATHER MONITORING SYSTEM

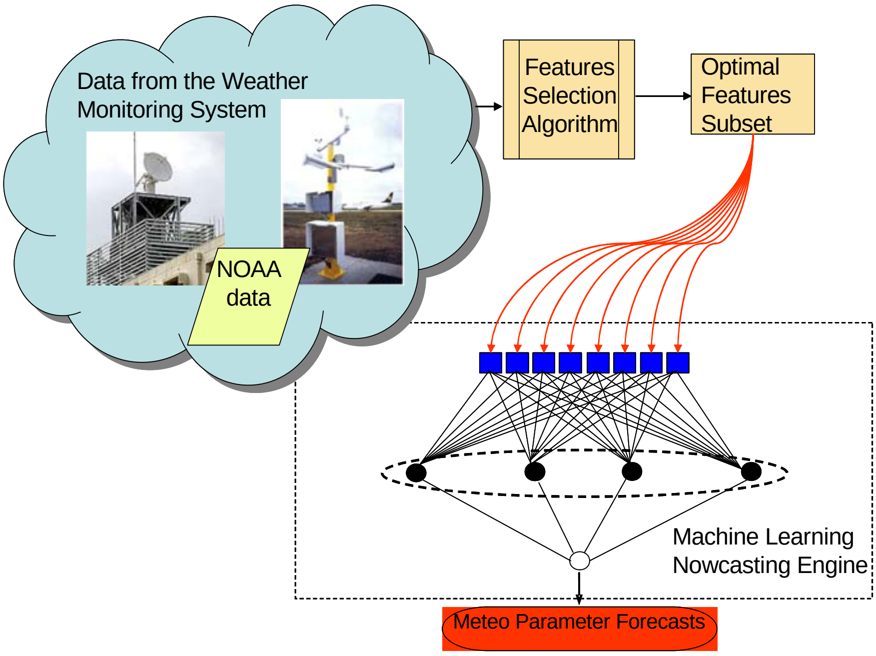
A network of weather stations will be installed at the airport in order to monitor the local weather conditions. First of all we have to study the optimal number and the positioning of these meteorological stations in order to characterize the airport at its best. These stations measure the common meteorological parameters of a synoptic net: air temperature (°C), ground temperature (°C), air humidity (%), precipitation (mm), wind speed (m/s) and wind direction (° from North).
We have also to define the optimal technical requirements (in terms of cost, operation and reliability) that the sensors have to respect such as: Measure Field, Repeatability, Accuracy, Resolution, Response Time, Protection Degree (IP) given the particular application, Power supply and Output interface.
All local parameters are then integrated by some NOAA data (essential for the forecasts of phenomena such as fog and snow) which supply information regarding the thermodynamic state and the stability of the atmosphere. In particular these variables are:

- PBL Height (Planetary Boundary Layer)
- Wind Speed and direction (500 - 850 mbar)
- Relative humidity Profile
- Temperature (500 - 850 mbar)
- Cloud cover base height

Furthermore the functionalities and the performances of small surveillance X-band radar will be improved, in order to use the received echoes for meteorological purposes. Improving Quantitative Precipitation Estimation (QPE) in case of both liquid and solid water phase requires the development of a radar signal processor (RSP) that is able to transform the received backscattered power into either rainfall or snow intensity during the winter season. The RSP must be able to operate in real-time; however, it could be linked and coupled with ad hoc adaptive routines operating in post-processing (rain-snow algorithm). These algorithms will be based not only on measured values of temperature and relative humidity, but also on forecast values. The rain-snow algorithm has to be validated through the comparison with conventional measurements. Another important topic is the data format: synoptic stations, RSP and NOAA have to use the same format. In this way the system is ready to collect the data used by the forecasting software and the numerical forecast algorithms can work together.

4. WEATHER NOWCASTING ALGORITHMS

Weather forecast systems are among the most heavy equation systems that a computer must solve [1]. A very large amount of data, coming from satellites, ground stations and sensors located around our planet give every day information that must be used to foresee the weather situation in next hours and days all around the world. Weather reports give forecast for next 12, 24 and 48 hours for wide/mesoscale areas [2]. Today they are quite reliable but it is not unusual that in a restricted region the conditions suddenly change. A different strategy will be used during the project. “Nowcast” [3] means a forecast restricted to next three hours in a very limited area. This new approach where the data fusion is performed with soft-computing techniques is far less time consuming than the algorithms used in traditional wide areas weather forecasts. Nowcasting does not replace the traditional weather report but it allows having an accurate estimate of the weather conditions in next three hours that can be a useful tool during winter emergencies at the airport. The adopted forecasting software is strongly related to enhancements to the “NEMEFO” system [4], developed at the Polytechnic of Turin, which is a nowcast system. It uses data sampled every 15 minutes by means of a meteo station and forecasts the evolution of these data in next three hours. The AWIS nowcasting algorithms will be based on several techniques of data-mining (artificial neural network ANN, support vector machines SVM, etc.). In this way the system turns out more reliable being made by a committee of algorithms. The ANN and the SVM have been often used in time series forecasting [5, 6, 7, 8, 9, and 10]. In particular SVMs are a statistical learning technique, based on the computational learning theory, which implements a simple idea and can be considered as a method to minimize the structural risk [11]. The design of the nowcasting software will include the choice of the appropriate architecture and topology of the adopted machine-learning tools (architecture, topology, number and transfer function of the hidden neurons and training algorithm for the ANNs; kernel type, cost function and optimization algorithm during the training phase for the SVM). Furthermore it will be selected the optimal configuration of parameters such as, for example, the number of hidden neurons for the ANN and the hyper-parameters values for the SVM. The research is focused also to maximize the ratio performance/elaboration time. In fact such techniques, being data-driven, improve their performance through time; but the data growth implies the time of elaboration increases too. Therefore the best solution is obtained through experimental tests. Moreover it is developed a “data pre-processing” algorithm in order to extract the best set of meteorological variables necessary to foresee a determined phenomenon. An information theoretical approach to feature selection will be applied in order to determine the best subset of features by means of a proper backward selection algorithm based on the Parzen method [12]. This step is fundamental because it simplifies the complexity of the system. So we will develop a data mining system consisting of two computing blocks (Picture 1). The first one implements the feature selection algorithm and produces as an output the optimal subset of features. This optimal subset can be fed as an input to the second computing block that is the machine learning engine of the system and whose output is the estimate of the parameter to be forecasted.



Picture 1: Weather Nowcasting System

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5. SPECIAL SENSORS INSTALLATION, SETUP AND TEST

One of the most important factors of a modern RWIS is the continuous monitoring of the pavement condition. The detection of water or ice presence, included also the ice formation, is one of the most important information about road safety. In this way the possible water or ice thinnest layers formation on the road can be immediately detected; consequently the appropriate precautions can be undertaken. The ice sensor developed by the Polytechnic of Turin is a high quality device to monitor pavement temperature and condition. Conventional ice detection technology relies on large scale sensors that often require elaborate assembly, handling, and installation procedure. Furthermore, most of the systems used e.g. for ice detection on airplane wings [13,14] cannot be used for road surface conditions monitoring due to the fact, that the systems have to be installed into the surface of the roadway. This requires that the sensor has to be strong enough to bear the weight of vehicles, or to be resistant to chemical substances that are likely to occur on roadways (such as salt, fuel, or oil) and that could damage or make inaccurate the sensor. Generally, ice detection systems can be categorized as indirect or direct. Indirect systems do not monitor the actual surface conditions, but instead attempt to predict the presence of ice by measuring several parameters such as air temperature, humidity, pressure, ground temperature and/or water presence. Systems, based on direct measurement, utilize a variety of very different technologies such as microwaves or infrared radiation, which are one of the most reliable but expensive technologies. In this case the ice detection is realized by measuring the waves reflected from the surface under observation, because water and ice have different reflectance coefficients. On the other hand vibrating probes can be used [15]. With this method ice detection is established by analyzing the variations in frequency of the vibrating probe that results from an accretion of ice on the sensor. However, the presence of vehicles or the deposition of dirt can quite easily make ineffective vibrating probes. Anyhow, both methods are quite expensive and cannot be deployed in many critical situations. Therefore, some less complex and less expensive systems exist that detect the presence of water or ice mainly by measuring the different conductivities or dielectric constants [16] of ice and water by using two pairs of exposed electrodes. These capacitive systems are particularly interesting, because only the stable electrodes have to be exposed to the mentioned stress [17, 18, and 19]. Most of these systems, however, detect the presence of ice or water only due to a change of the measured values (capacitance or conductivity) and require a temperature sensor in order to distinguish between them. Obviously, the main drawback of these methods is that the presence of salt in the water on the surface modifies the freezing point of water and therefore the measurement is not reliable any more [20]. In order to solve this problem active solutions exist which determine the freezing point of the liquid on the surface by cooling and heating the liquid on the surface above and below the freezing point, allowing a reliable detection. However, these systems require a lot of electronic for this type of detection, and have high power consumption. For these reasons, the ice-sensor developed by the Polytechnic of Turin utilizes the advantage of the cheap and efficient technology of the exposed sensor's electrodes, but provides a completely new solution to the problem of the possible contamination of the present water, which makes the system both highly accurate and extremely robust. Generally, the capacitance value of the electrode assembly depends on the geometrical configuration such as distance, shape, and dimensions of corresponding surfaces of the electrode assembly and also depends on the relative permittivity of the material provided between the electrodes. The relative permittivity, in turn, depends on the temperature of the substance and a measurement frequency with which the capacitor is operated. Thus, we use a new measurement device able to detect small changes of the capacity of an electrode assembly at several different frequencies [21, 22]. Such sensors are placed in the runway in order to detect ice formation.

Another important topic is the choice of the best locations where these devices must be placed. A logistic study is necessary in order to establish the better positioning (influence beam) of the sensors for a meaningful monitoring of the entire track. Moreover it is studied and fixed the optimal installation solution compatible with the mechanical characteristics of asphalt of the airport track. At the same time the airport's maintenance salt spreaders are equipped with the infrared sensors to monitor on the go the runway temperature. This sensor has a fast response time: it adapts itself quickly to the temperature variations.

4. CONCLUSIONS

This paper presents the project of an Airport Winter Information System (AWIS). The goals of an AWIS are various and contribute to a higher safety level of the airport especially during winter emergencies and result in an improved image of the airport reliability. Obviously, a great synergy has to exist between the airport and the runway management. Therefore the project involves the management of the international airport of Turin, Italy, which will be the first airport to test such a safety system and to provide a reference model. But an AWIS can strongly improve all the aspects of the service of the winter events, such as weather reports, control of the pavements conditions, field condition assessments, passenger's safety, and global air traffic efficiency. All these aspects will be verified on the Turin airport during the three years long project. But the ambitions of this project are much more foresighted. The final AWIS packet will be the studio of a prototype system to be used in any airport. The new techniques studied to improve the behavior of the pavement during winter events will be used by asphalt companies for other similar applications. The knowledge of the behavior of these pavements with rain, ice and snow and the techniques used to optimize the de-icing treatments will be an improvement for salt spreaders systems. Local meteo forecast systems will be strongly improved by the new nowcasting tools that will be installed and tested in the airport to prevent dangerous winter events. Also new short distance radar will be developed to forecast snow precipitations in limited areas. Last, but not the least, efficient models of data treatments and information communication will be studied to have the maximum efficiency both from the air traffic management (ENAC) and from the passenger point of view.

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