Final Report for Aurora Program Project 2002-01 – Intelligent Image-Based Winter Road Condition Sensor – Phase II

Contents

Summary

This document is a report concerning the R&D project "Intelligent Image-Based Winter Road Condition Sensor – Phase II". This project builds on earlier research [1] in the area of automated road condition classification. Its intent is to develop, integrate, and evaluate hardware and software for automated classification of road surface conditions in winter, which can be connected to an RWIS RPU. The system has been tested during spring 2002 in a test site located 5 miles east of Östesund, in central Sweden. The test has worked out well, and the results show that no serious operational problems have occurred.

Camera images from the test site have been collected in large numbers, and these pictures are now under evaluation. Depending on the results from the evaluation, these images may be used as a part of the neural network trainings in the final system.

History

R&D projects were conducted over several years to develop an automated system for road condition classification using neural network technology. Two methods have been used, one with image data (MARCONI) and one with sound data (ARCANA). Projects utilizing these two methods provided very promising results. They were followed by development of a hybrid method using images and RWIS data. The first two projects are completed and what remains is to develop a working application of the concept.

Objective

This R&D project is focused on further development built on earlier results achieved in the area of winter road condition classification by using images and, in particular, images taken in night time. The main purpose of the project is to evaluate the application of earlier R&D results, in a product that complements other RWIS sensors. As part of the analysis, an integrations test has been performed.

Definitions

Shortening/Notion	Meaning
MARC	Name of the equipment for image analysis
GMC	General measuring central
MS4	Swedish National Road Administration RWIS station version 4
PC/104	Standard for a small compact PC hardware.
VViS	Swedish for RWIS
JPEG	Joint Photographic Experts Group
DAP	Data Acquisition Process
Neural network	Mathematic model inspired by the nervous system and how it treats information
RAS	Remote Access Service

Integrations Test

This test included construction of a computer system for image analysis and integration with an RWIS model MS4. Images were downloaded from the MS4 camera and analysis results were then brought back to the MS4 RPU. The analysis program module consists of source code developed earlier in the MARCONI project with some modification and adaptation to existing source code in MS4.

The system was adapted for winter outdoor conditions and installed in Torvalla, located 5 miles east of Östesund, in central Sweden. Tests were performed during the spring of 2002. The location was chosen to provide winter road conditions, and the objective was to evaluate the potential for analyzing nighttime pictures with infrared lighting.

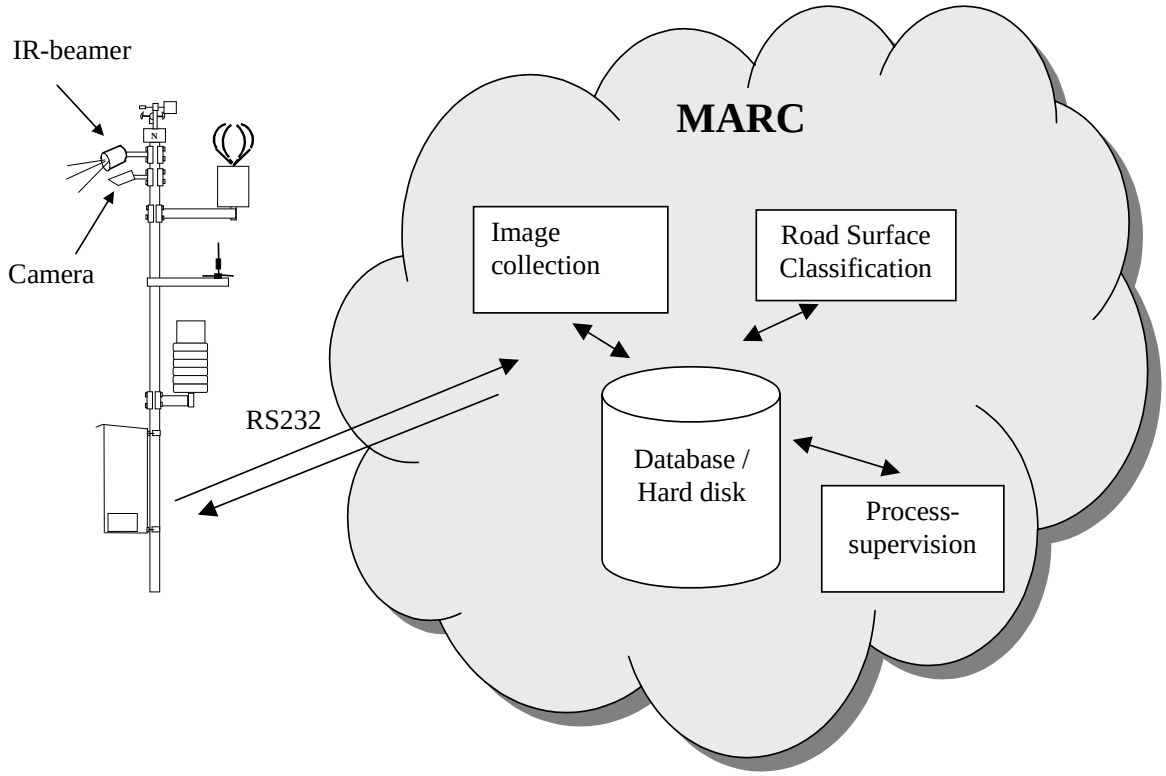


Figure 1. MARC system

MARC

This system is a further development from the earlier MARCONI and ARCANA systems, which has resulted in the new generic name MARC. Figure 1 indicates the elements of MARC. We have chosen to use GMC for data collection during the development of this system. Figure 2 is an outline of the GMC platform.

By using the GMC platform the basic system is already developed. The basic idea is as described above – to collect pictures from an MS4 system. Those pictures will then be analyzed and the result sent back to the MS4. Two processes are needed – one collecting pictures and delivering results to MS4 and one doing classification. Those two processes were developed and implemented as follow.

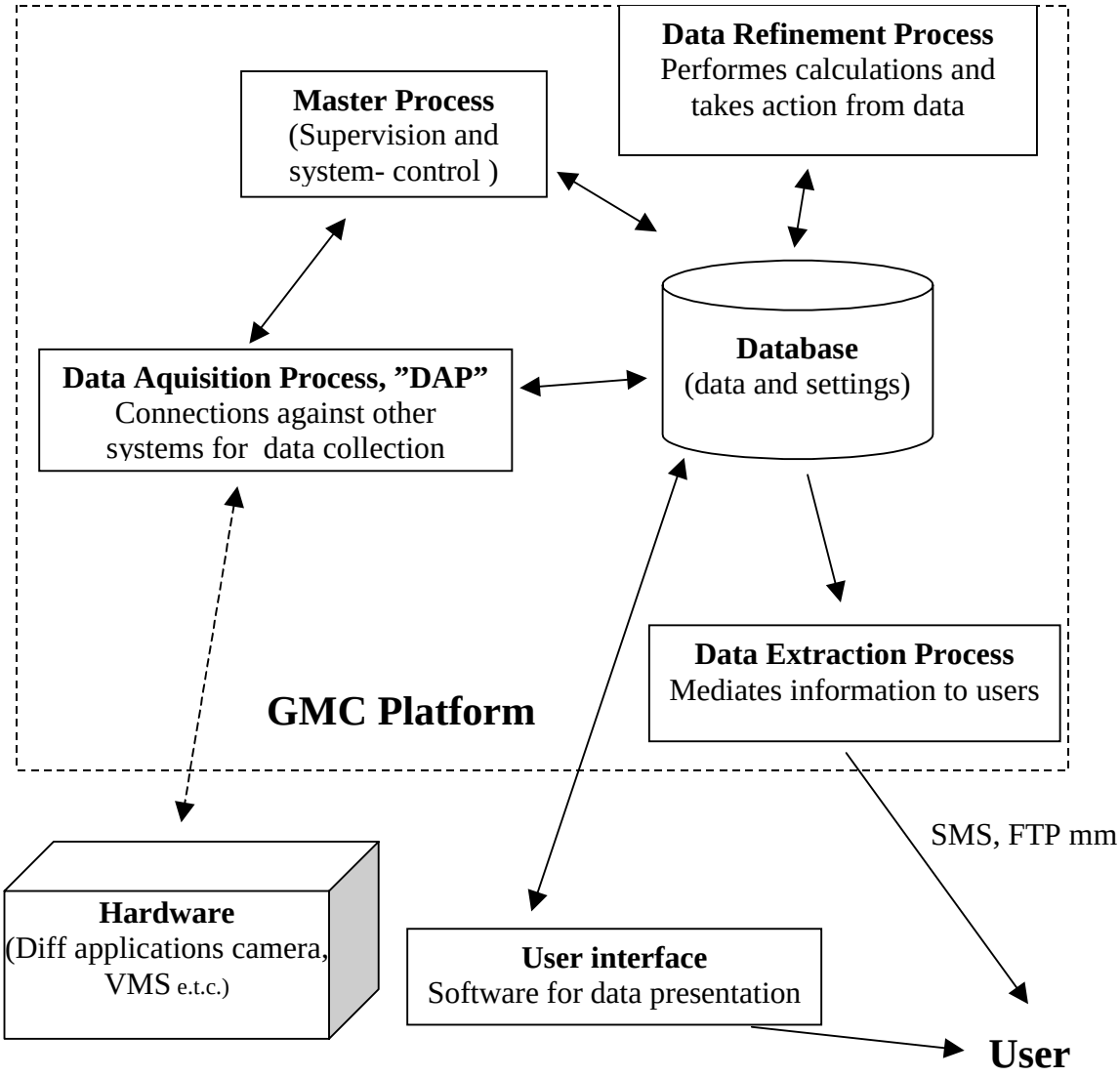


Figure 2. GMC platform

DAP_MS4*:*

This process is developed from already existing software. DAP_MS4 is normally used to collect RWIS data and camera pictures from MS4. The process can be configured to determine what data is collected. For this project only pictures were collected. Once collected, the pictures are converted to JPEG-files, information concerning filename and the date of file collections is added and they are stored in a database. Besides collecting pictures, there is a need to store the results from road surface classification in MS4. DAP_MS4 will read the latest road surface data from the database and store that information in MS4 by using a newly developed command. See the MS4 part below.

***DRP_NN**:*

DRP_NN is the process that performs the road classification. This process uses the code that was developed earlier in the MARCONI project [1]. The code is structured to make a more obvious interface between the mathematical element and the element that deals with input data and results. Therefore, an issue arose with adding new functions concerning both new mathematic details and other changing needs. The following gives an overview of how the process works. DRP_NN:

1. Checks the database table **DataMS4camera** for the filename that belongs to the latest stored road condition picture.

2. Checks the database table **DataNN** if this picture is already treated. If so, the session ends, otherwise go to item 3.

3. Converts picture from JPEG forma to raw data.

4. Masks irrelevant parts in the picture.

5. Calculates characteristics for the present picture.

6. Performs road classifications of the picture by using the calculated characteristics.

7. Calculates confidence value.

8. The result from the classification is stored in the database table **DataNN**. Besides the result itself we store the characteristics for every picture done. This information is not needed for the end users, but could be of interest during the development of the final version of this program.

Functionality in GMC makes it possible to use the processes in several different ways. As described above, one can configure how the DAP_MS4 will work. That makes it easy to determine how often one wants to update the MS4 with new road classification data. All processes work independent from each other. The processes are configured to start with DAP_MS4 and only collect data.

Second the DRP_NN will perform the classification, and finally the DAP_MS4 delivers results back to the MS4 RPU. The whole sequence can be performed every 10th minute. Because of this we can guide how the processes will work, which gives us future possibilities. For instance, we could simply use average values.

One inescapable problem is that some of the pictures for one or another reason will be incorrect (e.g. vehicles in the picture). In addition, there could be situations where most of the pictures give the same answer and only one has a different classification. In that specific situation an average value would not be suitable. A median filtration where the deviating results are removed would be more suitable.

Hardware

The GMC normally runs on a Windows NT 4.0 platform based upon a stationary computer. In this project the platform will be used in field tests. A hardware platform was created to meet those needs. We concentrated on two hardware families for this purpose:

- Compact PCI
- PC/104

It was decided in this project that there should be an integrations test based on PC/104 technique. PC/104 is a standard developed in the middle 1980's and is used worldwide. The module that we used during the project has the following characteristics:

MSMP3SEV v3.7c

- CPU	P3 400 MHz
- RAM memory	256 MB
- Serial ports	2 st
- Parallel port	1 st
- USB	1 st
- IR-port	1 st
- Graphic card	Yes
- Network card	Yes
- Temperature range	-25°C till +60°C

MSMP3SEV contains all needed functionality despite its lack of storage medium. To solve that problem one can use a conventional hard disc or a flash disc. The benefit of using a flash disc is that it could be found in specific temperature-ranges. The drawback is that the cost of a flash disc is much higher compared to a hard disc. This was a determining factor when it was decided to use a conventional hard-disc, although we then had to develop external heating of the hard disc.

There are several different ways to solve this problem. One could place both the PC/104 card and the hard disc in a separate heated cabinet. That solution was taken under consideration but was estimated to be unnecessary though we had a large MS4 cabinet with a lot of space. To avoid reorganization of the entire cabinet only for the purpose of the hard disc, a separate box was produced. This box could then be placed inside the MS4 cabinet. Heating led to consideration of other possibilities that can occur (e.g. power failure or cut). Long power failures can lead to a cooling process of the hard disc. If the system restarts immediately when the power returns there is a high risk that the hard disc will be damaged because of the temperature. Therefore, a thermostat that controlled the temperature will be applied as shown in Figure 3 below. This will make it impossible to start the system before the hard disc reaches the right temperature.

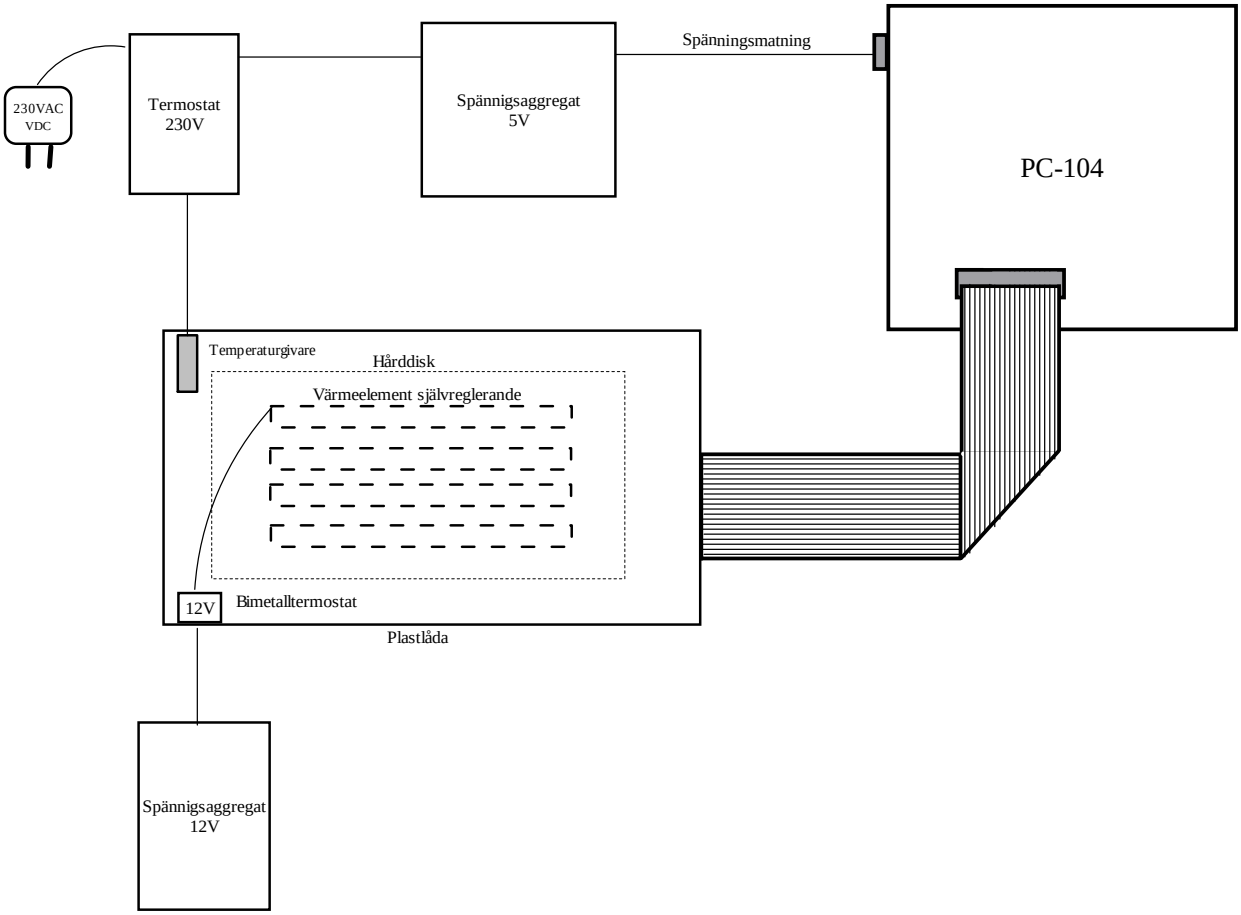


Figure 3. Schematic diagram of thermostatically-controlled power supply

The hard disc was placed in a box insulated with neoprene to reduce the loss of energy and create a system with smaller amplitude in temperature. Inside the box there is a thermo probe connected to a thermostat. When the temperature in the box is lower than 10°C the power to the PC/104 card is switched off. This switches the power off to the hard disc as well. To avoid overheating of the hard disc during warm summer days there is a small bimetal thermostat placed in the box. When the temperature is above 30°C the heating of the hard disc is turned off. Figure 4 shows how the different parts are placed in the cabinet. Pictures of various components can be found in Appendix 2.

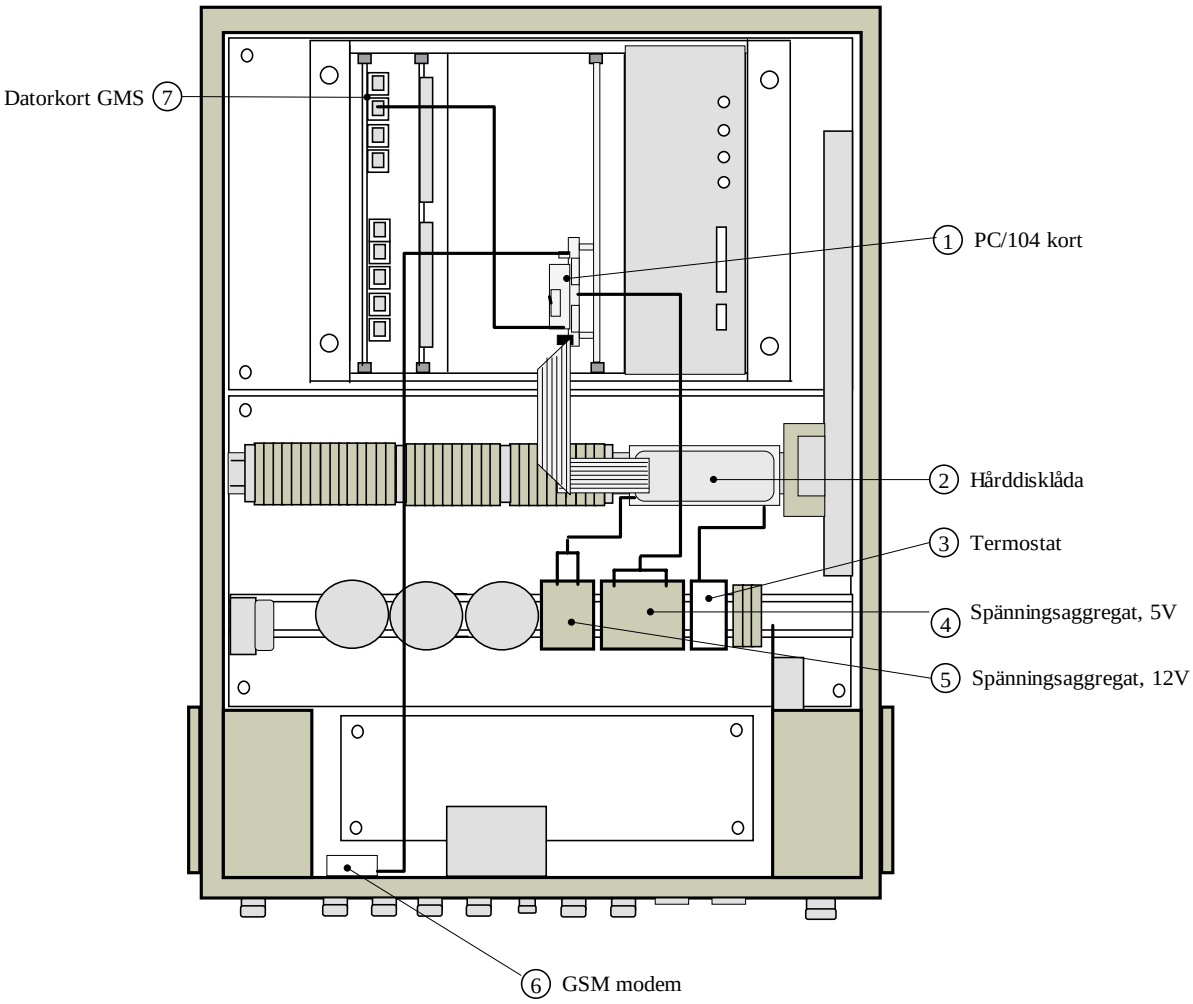


Figure 4. Drawing of GMC control cabinet indicating location of control parts

Events During Development and Integrations Test

The original MARC system was simplified by removing graphics routines that were no longer needed with the adoption of a digital RWIS camera, and Metric [2] computer hardware was substituted for the original About Industrial Computers AB [3] system due to reliability problems experienced with the latter.

Collecting of Images

The collecting of images together with a manual real-time processing of the road surface conditions proceeded for three months. We expected to have images from four predetermined types of surface conditions:

- Dry
- Wet
- Snow
- Ice

Unfortunately the weather was milder than usual and most of the images were only showing dry or snow conditions. There were no available images of ice and only a few with wet conditions. The amount of precipitation from the rain event was very small and the texture of the road surface caused it to dry up rapidly. The snow period provided large amounts of good quality images.

Future

Images from the test site showing dry or snow conditions are under evaluation. There are some new parameters that could have an effect in this evaluation compared to earlier tests in this matter. These parameters are:

- Different type of camera
- Day and night time images

The expectation is that the evaluation will determine if there are any influences from these new parameters. The quality of the nighttime images could be a subject for improvement. Provided that the evaluation of the new type of images does not change the entire project scope, the future aim is to make the training sets (including two neural networks, one for daytime and one for night time images) general and not location-dependent. The benefit of such a network would be decreased costs. The collection of images and the manual real-time processing takes time and is expensive.

Figure 5 shows an example of how to present the information on a map.

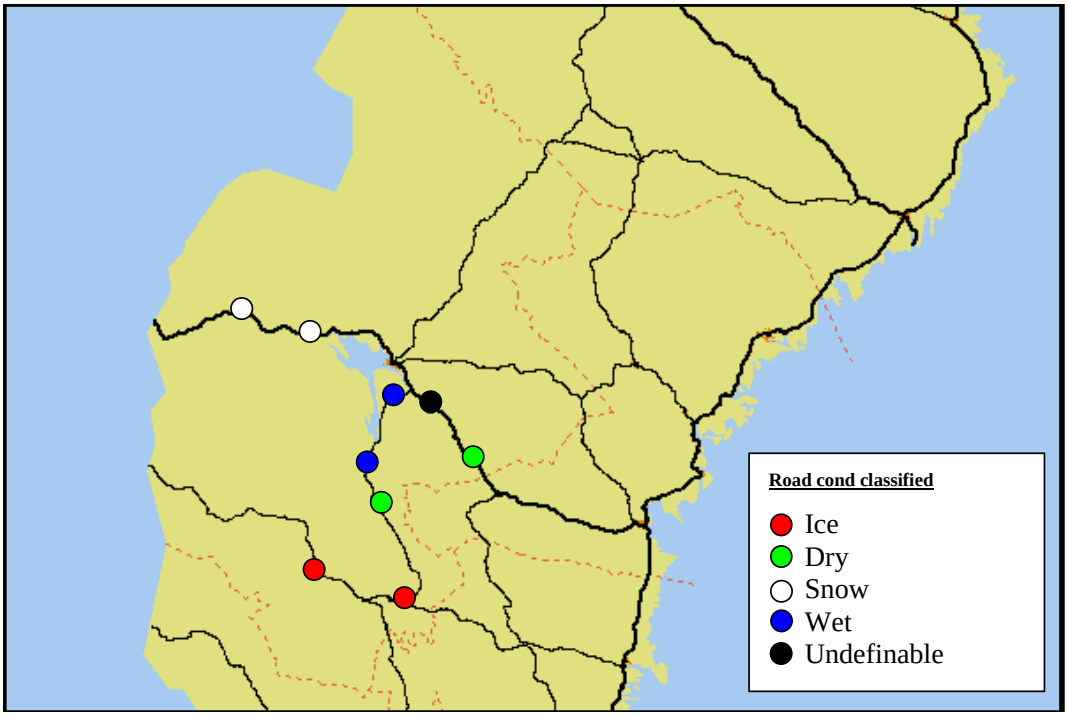


Figure 5. Example of data presentation to the user

For each separate RPU unit there will be a colored spot on the map that describes the road surface conditions at that specific place. If the confidence value is too low there will be a black spot instead, which means that the result is not definable.

One example of the type of information on which classification could be based is shown in Figure 6.

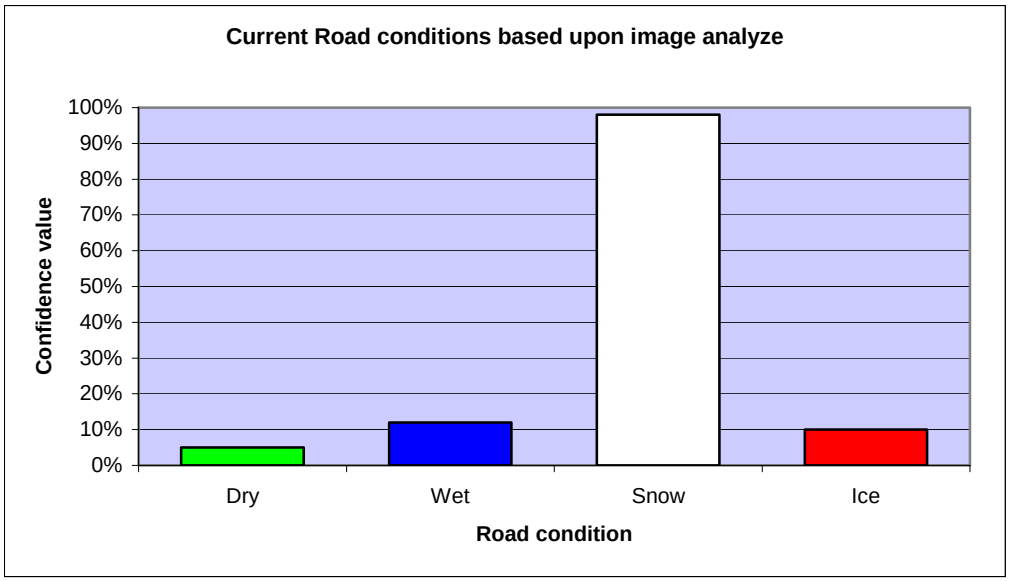


Figure 6. Example report of condition based on image analysis

Further information could be a historical presentation of the surface conditions over the last 6 hours. An example is shown in figure 7 below.

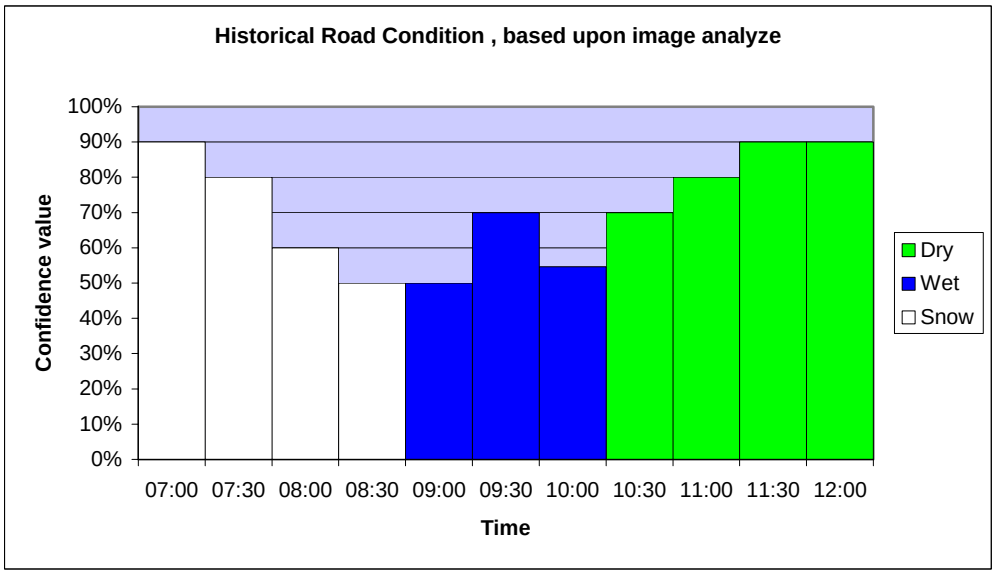


Figure 7. Example presentation of historic road condition based upon image analysis

Conclusions

This project has provided knowledge about how to design a final version of this system. Two neural networks are needed, one for daytime images and one for nighttime images. Of the remaining problems, the most difficult is the supply of training data to the neural networks (images with a manual real-time processing of the surface conditions). The second most difficult problem is to make the training sets general and not dependent on location.

References

[1] AerotechTelub and Dalarna University Final Report on Signal and Image Processing for Road Condition Classification - Aurora 2002

[2] Metric industrial electronics AB

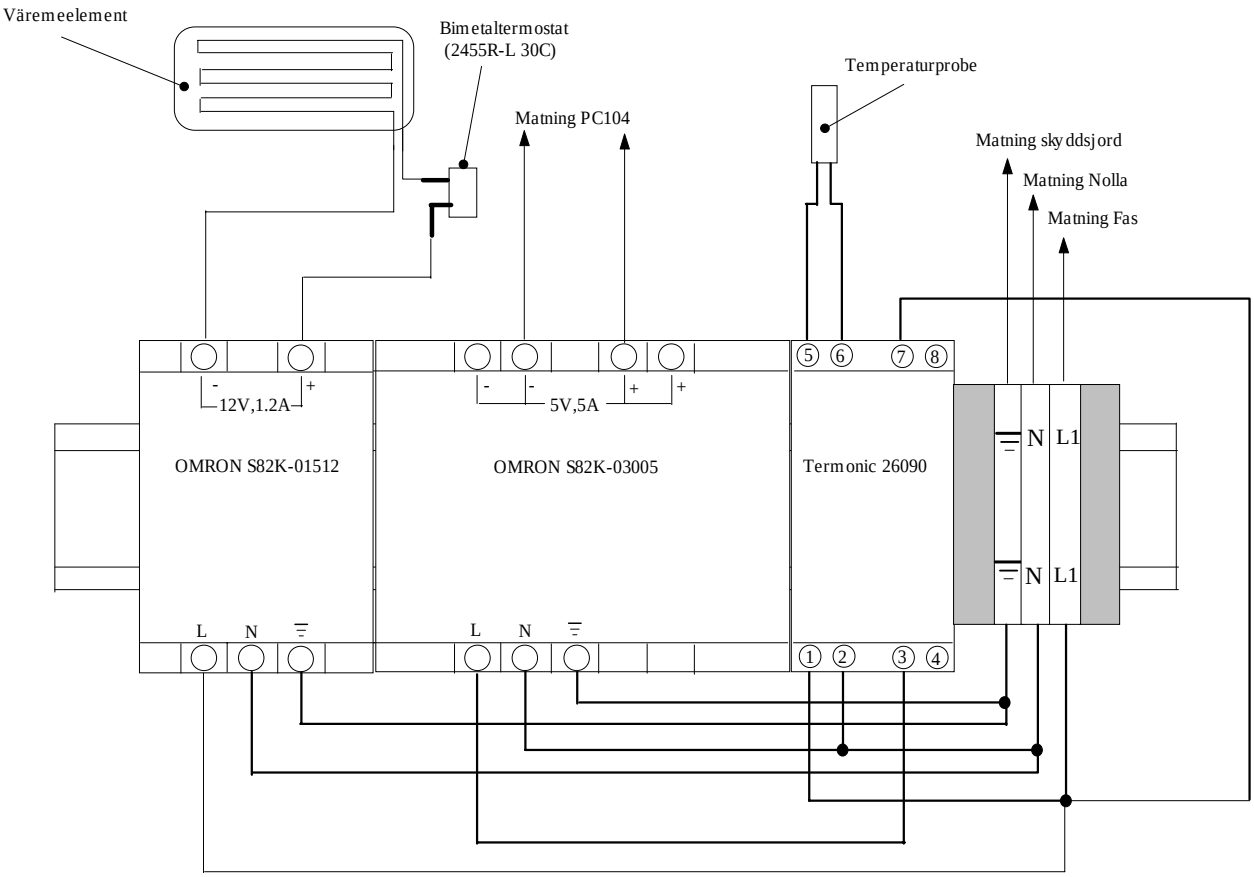
www.metric.se

[3] About Industrial Computers AB

www.about-ic.se

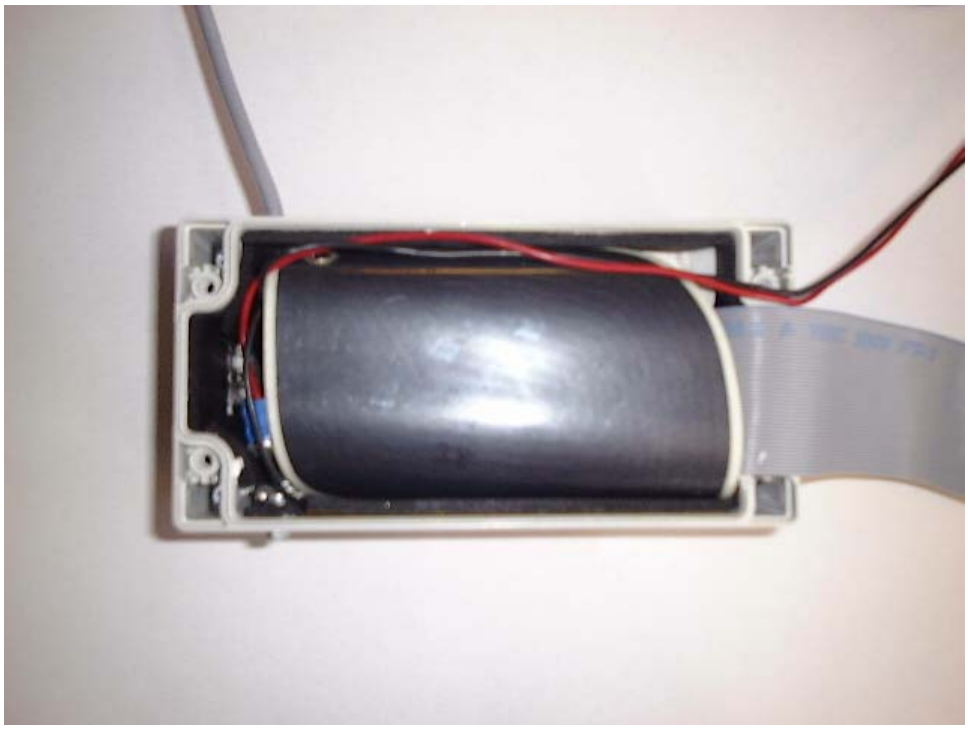
Appendix 1:

Anslutning av PC104-kort i MS4 skåp

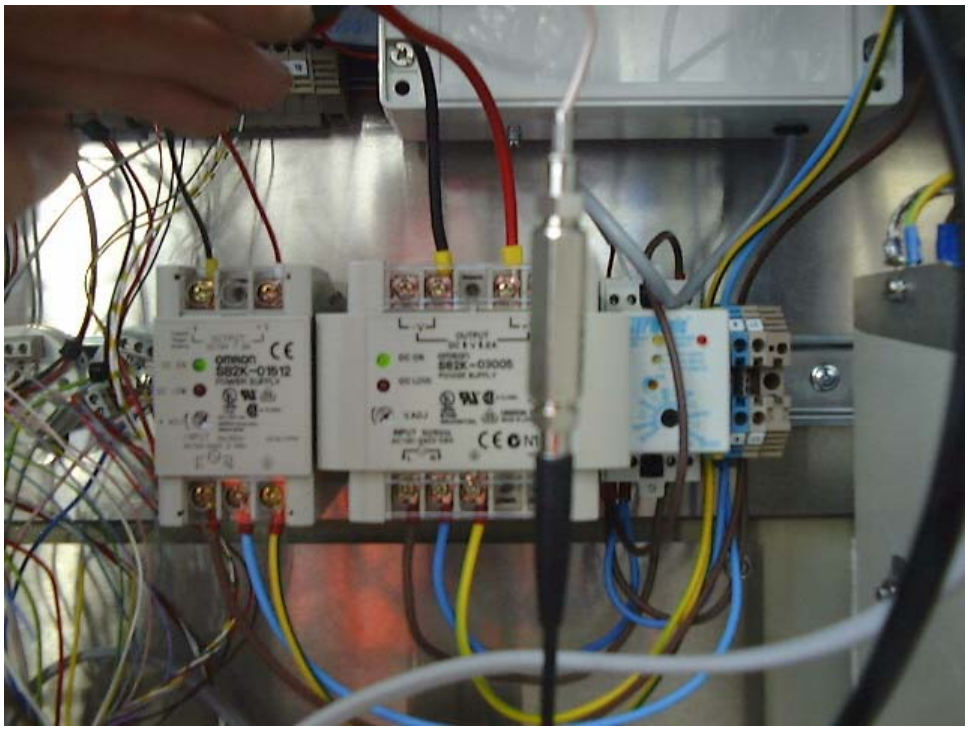


Appendix 2: Pictures of components found in the GMC platform

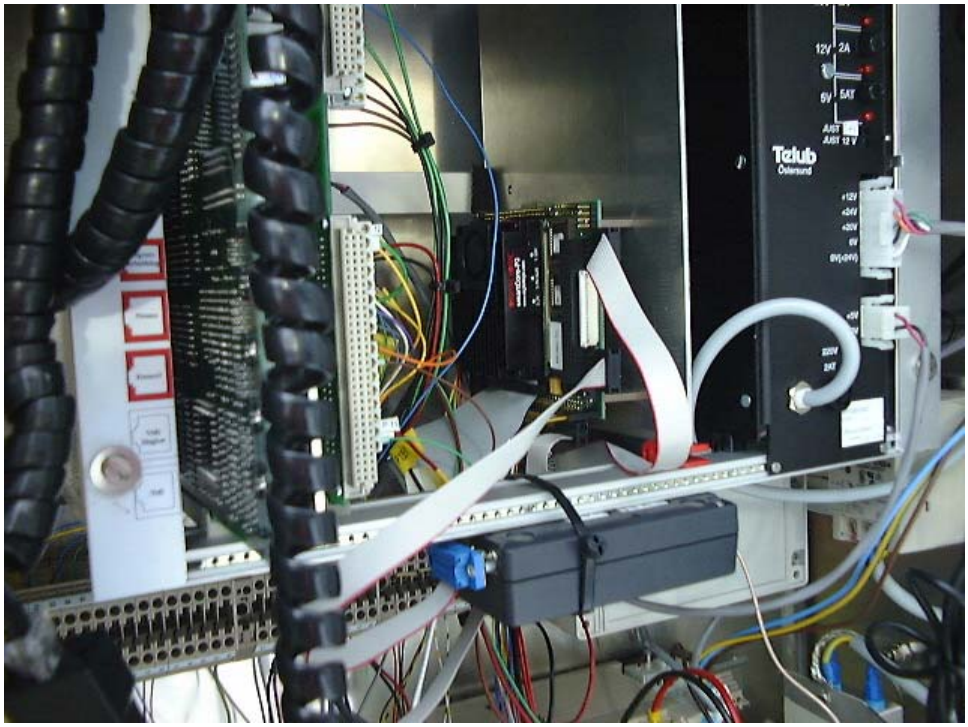
Hard disc box without electric heating.



Hard disc box with electric heating.



Voltage unit and thermostat in MS4. Hard disc box at the top of the picture.



PC/104 card mounted in MS4 rack.