OPTICAL RECOGNITION OF ROAD DE-ICING PRODUCT GRAIND'SEL PROJECT

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ABSTRACT

The aim of our research is to optimise the quality of road de-icing product spreading and to prevent over- and under-metering. To do so, it is necessary to get a precise knowledge of the mass and spatial distribution of the road de-icing product once spread on the pavement by a salt distributor. The Graind'sel project is two-folded. The first step consists in taking photographs of a pavement on which salt has been spread. The second step is the analysis of the digital images, which aims to determine the quantity and spatial distribution of the spread de-icing product. The method is based on analysing the digital images, and more particularly the luminosity content of the de-icing product. This original method consists in breaking up the de-icing product into unit grains, estimating its volume and finally, its mass. Each digital image represents a surface area of 1 square meter. Repeating this operation on a test section 3 by 6 meters enables us to evaluate the spatial distribution of the road de-icing product, as spread by a salt distributor under real operating conditions. Our goal is now to present this software program to the European technical committee of standardization TC 337 which is in charge of writing the Standard draft PR EN15597-2 relating to the approval of salt distributors.

KEY WORDS

ROAD DE-ICING PRODUCT / SALT DISTRIBUTOR / IMAGE ANALYSIS / STANDARDIZATION / GEOGRAPHIC INFORMATION SYSTEM (GIS)

1. AS AN INTRODUCTION

In July 2006, experiments were carried out during the technical committee TC 337 in Bingen, Germany in order to test different methods of checking spread road de-icing product so as to write the norm PR EN 15 597-2.

During this committee, we took remarkably well contrasted photos of salt that had been spread on a rubber surface area. These photos fathered the following question : is it possible to work out the mass of salt from a photo ? This would be an alternative approach to salt gathering and weighing.

Photo 1 – Salt on a rubber surface area.

This question is important. The German team suggests sweeping the salt before weighing it. Can we suggest a better solution ?

Photo 2 – Sweeping the salt before weighing it.

2. THE METHOD STEP BY STEP .

Photo 3 - Salt spreading.

Photo 4 – The basis of support used to take pictures, measuring one square meter.

Photo 5 – The setting up of the camera on the support.

Photo 6 – The photo taken by the camera

Photo 7 – The computer aboard, the support in the background.

Photo 8 – The automated reframing of the photo.

3. INVESTIGATING A WAY TO DETECT SALT

Salt can be seen on the photo : as its colour is clearer, it stands out against the dark background of rubber. An image processing should enable us to identify it accurately. On a rubber surface area, salt can be made out perfectly. What happens when using a real pavement ?

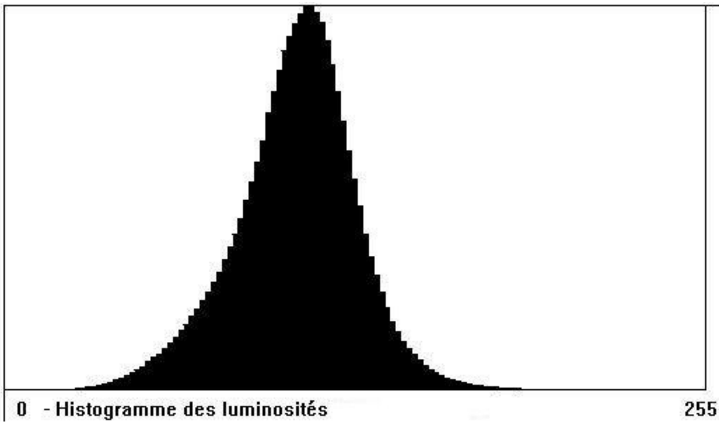
As the project consists in evaluating the operation of a salt distributor, we are able to keep under control the conditions under which the experimentation is carried out. We have chosen a real pavement but that has been " standardized ". The coating is recent, the pavement has been swept beforehand.

Likewise, the shooting conditions must be checked. Shadows and skimming sun must be avoided.

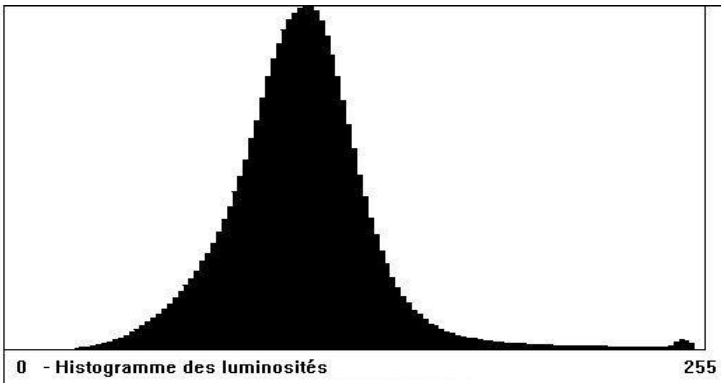
Photo 9– Standardized pavement without salt

Photo 10 – Standardized pavement with salt spread by hand

The tool which is able to detect salt is the histogram of luminosity. The latter shows the number of pixels for each level of luminosity. Luminosity goes from 0 for black to 255 for white.



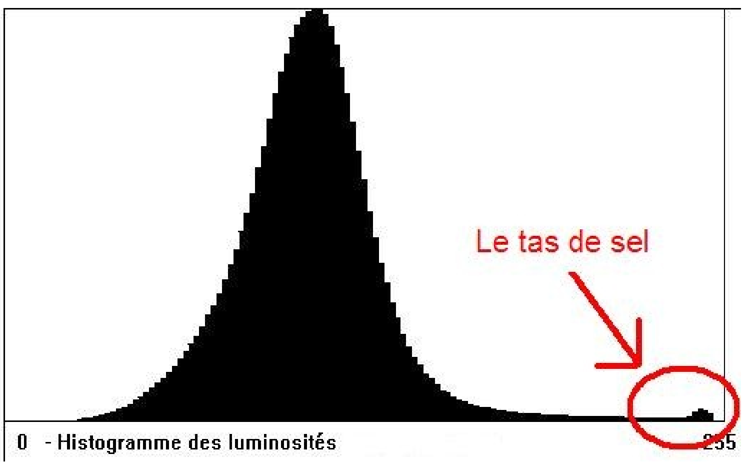
Ilustration 1 – Histogram of luminosity for standardized pavement without salt.



Ilustration 2 – Histogram of luminosity for standardized pavement with salt

In the bottom right-hand corner of this histogram, where luminosity is maximum, we can see a rise of the curve which is highly relevant. Indeed, these pixels are more luminous and indicate the presence of salt, of a small amount of salt.

This histogram of luminosity is a bimodal curve : it shows 2 maxima, that is to say 2 modes.



Ilustration 3 – The histogram and the presence of salt.

4. SALT MAPPING

Once the presence of salt has been identified, we have to delimit its outlines. Indeed, when we observe both histograms we understand that the luminosity brought by the salt is not limited to the rise of the curve in the bottom right-hand corner. The curve extends on the right. An isthmus links the pixels of the main mode to the secondary mode. This isthmus is constituted of pixels the luminosity of which has been slightly increased by the presence of salt.

The pixel dimension is 0.5 by 0.5 mm, so its surface is 0.25 mm2. The size of a salt grain can vary between a few mm to more than 1 cm, in length as well as in width. The surface of a salt grain depends on its granulometry. The surface usually varies from 1 mm2 to more than 1 cm2.

Each salt grain changes the luminosity of pixels, from a few to a few hundreds. The periphery of a salt grain also affects many pixels.

Photo 11 – A zoom in on salt grains

Therefore, we needed to set up a model in order to get a representation of salt on the pixels of the digital image.

The main parameters are the following :

1. The minimum luminosity that makes us consider a pixel as being affected by the presence of salt.
2. The geometric parameters that enable us to go from the 2 dimensions of a salt grain to its 3 dimensions : how can we go from the found surface to the expected volume ?
3. The method that consists in breaking up the large luminous areas made of pixels that are affected by salt. These areas correspond to juxtaposed salt grains that form a layer entirely covering the pavement. This method enables us to distinguish unit grains within a large cluster.
4. Salt density which is needed to go from volume to mass.

5. THE PARAMETERS OF THE METHOD

Each parameter is partly arbitrary by nature. Simplifying the complex reality to keep the essentials is a feature which is peculiar to models. This enables us to apprehend, if not completely, the real world. As far as this project is concerned we have come to the following decisions :

1. A pixel is considered as salted if its luminosity is higher than the following limit : the lowest point of the isthmus that links the two populations of pixels. We therefore do not take into account the pixels that are slightly affected by salt, that are those generally situated along the salt grain. By making this choice, the total surface area that is affected by salt is slightly under-estimated.
2. For each grain thus delimited, we look for the short and long axes and consider it as an ellipsoid of revolution. Proceeding this way allows us to calculate the volume of each grain. We made this choice after having discussed of another possibility : an average thickness that would have to be asked to the user of the computer application program.
3. In order to break up the large salted areas into unit grains, we are using a method that derives from the one used to break up territories into catchment areas. This method, used by Geographical Information System (GIS), consists, to simplify, in locating catchment areas as demarcated by watersheds. Likewise, a darker zone marks the granular discontinuity between two salt grains. Therefore, we will be able to apply the method regarding the volume calculation to the delimited grains.
   In order to prevent aberrations, a maximum limit for the surface area of a salt grain is also a parameter of the method.
4. We use the usual salt density : 2.17 g/cm3.

This method has been set up in a computer application program which analyses the fed digital image and whose output provides the mass of salt calculated according to these parameters. The calculation is almost instantaneous.

This computer application program is composed of two parts :

1. A DLL, Dynamic Link Library, which can be integrated in an computer application program.
2. A computer application program which includes a high-level Human Computer Interface. This program provides, besides the calculation of the salt mass, the following functions :
   - Display of the histogram of luminosity.
   - Layout of salt on the image : division into squares with or without salt .
   - Display of the salt grains in the image.
   - Breakdown of the counting: the number of salt grains for each salt mass.
   - Image processing of a « test section » : photos taken next to each other behind a salt distributor, for instance on a surface area 3 by 6 meters, that is to say 18 photos of 1 square meter. This image processing determines the spatial distribution of salt on the analysed surface area [1].

6. PRESENTATION OF THE COMPUTER APPLICATION PROGRAM

Here is the interface of the application program once a digital image has been opened. As soon as the file is opened, it indicates the dimensions of the pavement, the average luminosity, the detected presence of road de-icing product, and the luminosity limit « Salt/Pavement ». Here is displayed the histogram of luminosity

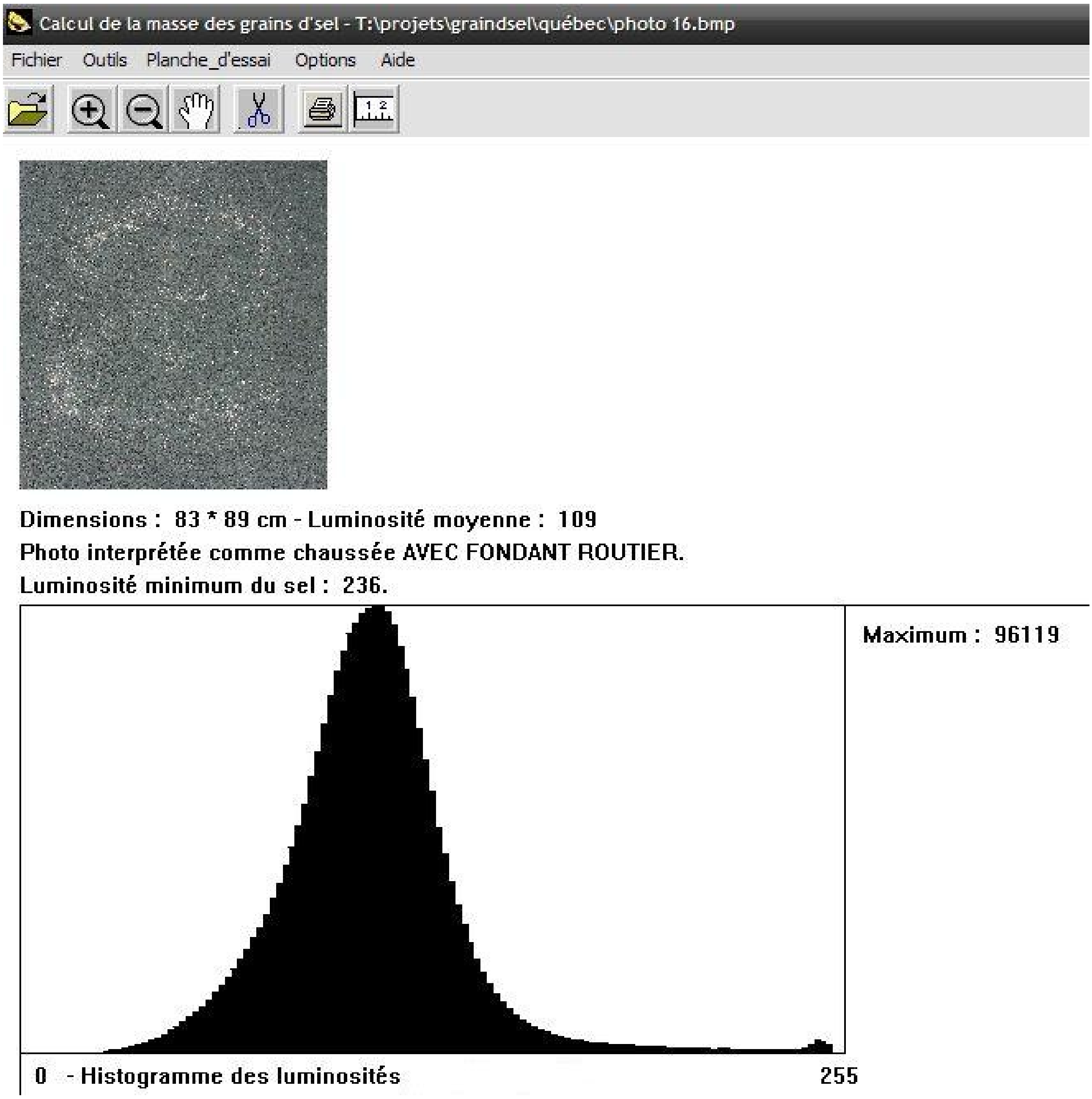


Illustration 4 – The Human Computer Interface of the application with photo and histogram.

Here the application program cuts the image out into squares with or without salt. This division shows, for this photo, a very good spatial distribution of salt on the pavement :

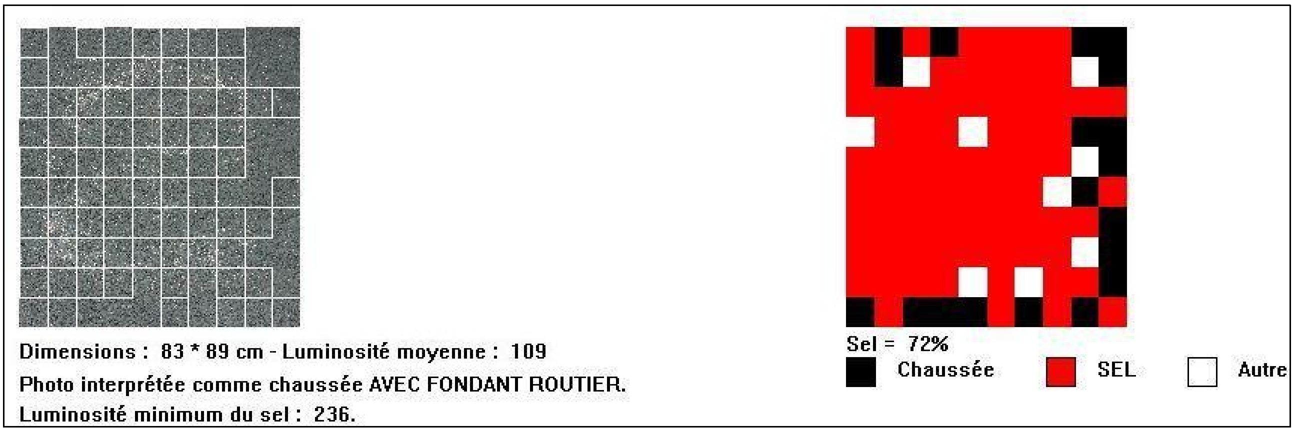


Illustration 12 – Division of the photo into squares with or without salt.

Here the application program colours the salt grains that have been located on a zoom in :

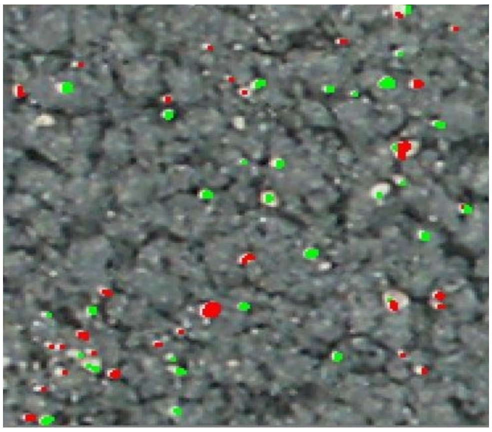


Illustration 13 – The application program colours the salt grains.

Limite du sel dans l'histogramme précise.
Limite luminosité minimum des grains à : 236

Il y a 1850 pixels pour un mètre.
La surface de la chaussée est de 7517.6 cm2. (89.8*83.7 cm)
La surface du sel est de 44 cm2. soit .59 % de la chaussée.
Nombre de grains de sel : 3941
Le volume calculé est de 6.33 en cm3.
Soit une masse de 13.7 grammes. (masse volumique = 2.17 g/cm3)
Soit une épaisseur moyenne des grains de 1.4 mm.

Soit une masse de 18.3 grammes par M2.

Nombre de grains par superficie en pixels :
1318 grains < à 1 mm2 : .45 grammes.
1812 grains < à 2 mm2 : 3.59 grammes.
442 grains < à 3 mm2 : 2.7 grammes.
158 grains < à 4 mm2 : 1.68 grammes.
119 grains < à 5 mm2 : 1.96 grammes.
39 grains < à 6 mm2 : .92 grammes.
18 grains < à 7 mm2 : .56 grammes.
16 grains < à 8 mm2 : .64 grammes.
10 grains < à 9 mm2 : .49 grammes.
2 grains < à 10 mm2 : .12 grammes.
un seul grain < à 11 mm2 : .06 grammes.

Board 1 – Beginning of the listing which provides the counting of the salt grains.

7. THE TEST SECTIONS.

Conducting a test section consists in shooting methodically the surface area of the pavement previously salted by a salt distributor. Here the surface area which is analysed measures 6 meters by 3 meters, that is to say 18 photos.

The application program enables the user to set the parameters corresponding to the conditions met when taking pictures of a test section. Then the image processing starts with no need of further intervention.

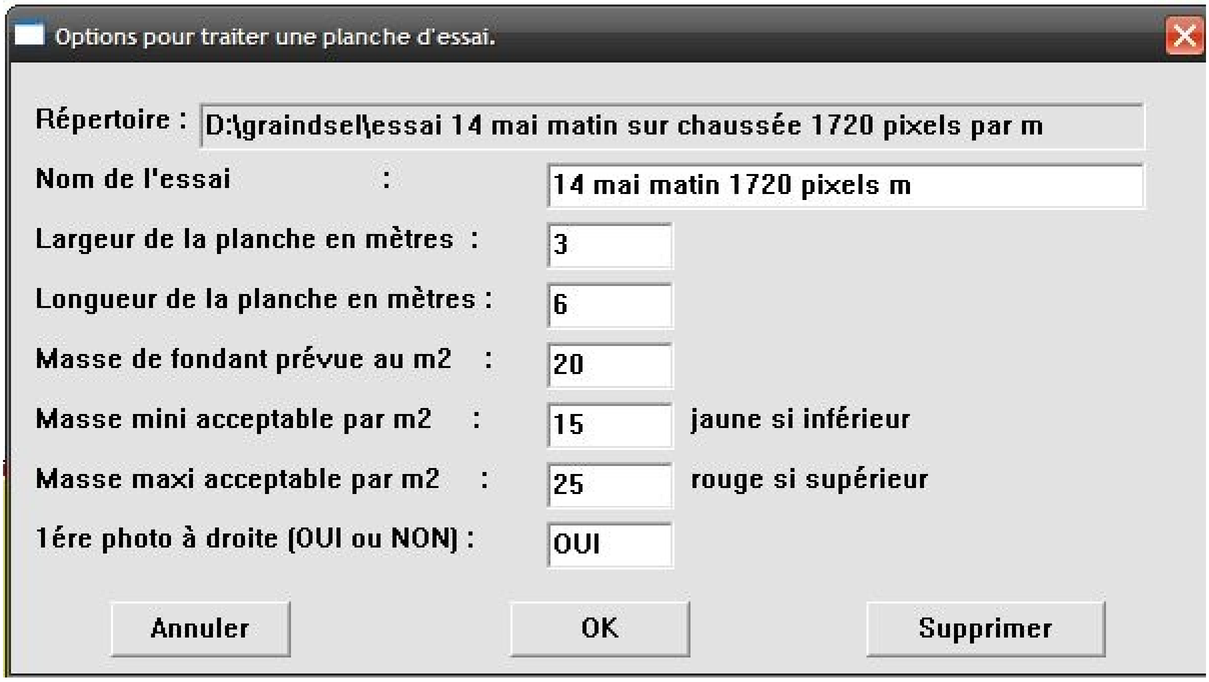


Illustration 5 – Dialog box used to set the parameters of a test section.

The result is colour-coded : green shows that the salt quantity is correct, red is excessive, and yellow is insufficient. The application program has not recognized the grey photo as being analysable, a case due to the bad lighting conditions of the shooting.

Here the test section clearly shows a bad spatial distribution of the road de-icing product in comparison with the expected result.

Photo 14 – Result of the analysis of a test section 3 by 6 meters.

8. FUTURE PROSPECTS

The computer application program has proved its efficiency under the tests conditions.

Nevertheless these results depend on the granulometry of the spread salt grains, on the texture of the pavement and on the amount of lighting. Another goal of this project would be to take into account brine as a road de-icing product. The volume would then be calculated according to the average thickness of the spread de-icing product.

The Graind'sel project is therefore involved in researching innovative tools for adjustment and checking of salt distributors in order to improve the performance provided by this winter service technique.

REFERENCES

[1] RGRA N°869 - Septembre 2008 – L'optimisation des épandeuses de fondants routiers