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Visual Inspection indexes obtained by Computer Vision monitoring

#ICA4point0

Adrián Rey Fuertes
Researc her, ASIMOB, Spain
adrian.rey@asimob.es

Ibon Arechalde Ugarteche
CEO, A SIMOB , Spain
ibon.arechalde@asimob.es

Beñat López Arantzamendi
CTO, A SIMOB , Spain
benat.lopez@asimob.es

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ABSTRACT

Visual road inspections have been applied during decades in order to ensure that the status of the pavement is good enough to be used by the vehicles , the Road Safety conditions are enough to avoid risks and also to evaluate the investment needs for the road.

These types of inspections had to be carried out by pavement experts, who had to be able to differentiate each type of irregularity detected, to analy s e the causes and evaluate de evolution of said degradations, and what were the necessary means for their repair.

Although theoretically any road in any country could be evaluated by unique criteria, the reality is that multiple road evaluation systems have been developed, using very different ratios. Among these systems, it is worth highlighting the American Pavement Condition Index [(PCI), defined in the standard ASTM D6433 , due to its wide use in areas of American The PCI considers 19 types of irregularities to obtain a rate from 0 to 100, from worst to best condition.

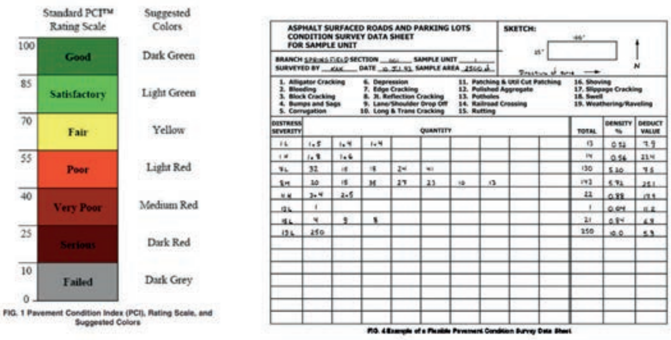

Figure 1. PCI score (applied in US) and example of a datasheet.

In Europe, each country has developed its own indices, with very diverse examples. In Spain there are different methods applied depending on if it is to be applied in a concessioned road (where each contract establishes the quality criteria for the evaluation), if it is to evaluate other type of main road, or if the analysis is for roads for low traffic intensity, where simplified methodology is suggested. In Belgium, on the other hand, the Center de Recherches Routières (CRR) developed the MF-89 method [2], that can be used on any type of road. This method explains the evaluation of the irregularities over three different type of pavements (Asphalt Concrete surface, Cement Concrete surface and Modular coverings) and uses weighting techniques to consider the relevance of each type of irregularity.

As explained in this MF 89 method, its correct application requires the compliance of the following points:

- development of a global database resulting from a preliminary survey operation
- evaluation of degradations to be encoded and their respective weight
- strict application of the encoding rules
- application of rules for calculating the visual index (VI) and the global index (GI)
- evaluation with the four classes and their respective thresholds in which the overall index falls
- best compliance with the "ten golden rules" for the pavement inspection

Until now, the training of the human inspectors was key to ensure repeatability and reproducibility of the evaluations and to comply with the "ten golden rules", when applying the method. Curiously, by using Computer Vision techniques, an automated evaluation of the condition of the road surface can be achieved, drastically limiting the safety risks for humans during the inspection on the road, and undoubtedly improving the repeatability and reproducibility of the evaluations.

The Computer Vision techniques enable the detection of all the irregularities that are visible from a camera, their classification according to the parameters established by each procedure and the analysis of the length and width of each defect and its position in the lane.

The post-processing of all these measurements allows the application of the weighting formulas for each road evaluation system, and the analysis of results, obtaining heat maps that allow knowing the needs of road rehabilitation and facilitate decision-making.

The current paper and the associated presentation explain how Computer Vision techniques have been applied to detect the irregularities in the pavement and how the method MF-89 has been used to obtain the Global Index for the evaluation of the roads in Belgium. The paper explains also which are the degradations that can be detected by Computer Vision, which not, and how to consider the impact of the irregularities that cannot be detected.

Finally, the paper explains how to extend the use of the Computer Vision solutions to the visual inspections of roads in other countries.

INTRODUCTION TO THE MF-89 METHOD

The Centre de Recherches Routières sited in Bruxelles is a centre dedicated to road research. The auscultation of the pavements is a fundamental aspect of the activities of the centre. From the 1950s, the CRR has been gradually equipped with diverse tools intended for pavement diagnostics both surface and structural.

The MF-89 methodology deals exclusively with the visual inspection of damage encountered on the surface of pavement. It considers the three types of common coatings (cement concrete, bituminous concrete and modular elements). Its objective is to present a uniform method for evaluating a network of municipal roads (or similar) and is intended to optimize its management. This methodology, which aims to be realistic and "practical-pragmatic", is currently voluntarily limited to the essentials, that is, to the evaluation only of the state of the roadway. It therefore does not consider currently neither the drains, nor the cycle paths, sidewalks, etc.

For the application of the methodology, a qualified inspector carries out a visual inspection of each sub-section in which the network is divided. Only the degradations specified in this methodology will be encoded. For each subsection a visual index IV is calculated whose value will be between 0 and 0.9.

The behaviour of a section or subsection of a road may differ from the rest of the network, so specific data of each (sub)section are required to predict the evolution of pavement deterioration. This is why at least an annual inspection of the road network is recommended in order to detect on which (sub)sections road wear is above average or lower than average.

For the practical implementation of the visual inspection in the field, three different ways are mainly proposed: (a) on foot, (b) from a vehicle or (c) on the basis of photos.

a) When the inspector walks, equipped with an odometer (to measure the distance), he/she observes visually the degradations and takes notes. This way is not applicable on certain high- risk roads that have, for example, high density of traffic and/or at high speed and lack sidewalk. In any case, the training of the inspector is crucial to avoid differences in the application of the methodology among different inspectors.

b) The inspection using a vehicle is based, up-to-now, in on-board tools that allow the encoding of degradations from a vehicle moving at an average speed of 5 to 7 km/h. The vehicle requires two people, a driver and an inspector, and the encoding of degradations is carried out in real time on a touch screen. This implies that the inspector has extensive experience.

Indeed, the encoding errors cannot be corrected easily.

c) This inspection is performed on the basis of photos, and uses a photographic recording device mounted on the front of the measuring vehicle to take a picture every x meters of the road surface and saves the images with the GPS coordinates. Speed of the vehicle is the same as the rest traffic on the road. Only the driver is needed in the vehicle. An inspector then carries out the encoding of the degradations on a computer dedicated software, using recorded photos.

Thanks to this method of work, the visual inspection takes place under secure conditions for the inspector and for road users. It is indeed important to inspect in the same way (i.e. in the same direction), year after year.

The inspection carried out on the basis of photos has the advantage of obtaining also a bank of image data from all the road network. The shots can be made in the best weather and light conditions... In return, identification of damage may be less accurate.

In any case, the correct application of the MF-89 methodology requires careful consideration of the following aspects:

- Initial elaboration of a global database with the results of a preliminary survey operation.
- Ensuring that degradations are correctly encoded and assigned the right weighting factor.
- Harmonization and training of encoding rules for all the inspectors along the time.
- Correct calculation of the visual index (IV) and the global index (IG).
- Assignment of each road sub-section within the four I_G classes (see fig. 2).
- Best compliance with the "ten golden rules" designed in Belgium for safety during the pavement inspection.

Once applied the process, the (sub)sections of roads obtain a road score called Global Index (I_G)

Classes I_G	Mesure d'entretien	Commentaire
$0{,}9 \geq I_G > 0{,}8$	Entretien de routine	Aucune réparation nécessaire
$0{,}8 \geq I_G > 0{,}5$	Réparations locales	Réparation des dégradations locales uniquement
$0{,}5 \geq I_G > 0{,}3$	Réparation générale	Réparation des couches supérieures sur toute la longueur de la section de route
$0{,}3 \geq I_G$	Renforcement	Intervention structurelle sur toute la longueur de la section de route

Figure 2. Table of Global Index (I_G) score.

INTRODUCTION TO COMPUTER VISION TECHNIQUES TO DETECT VISUAL ELEMENTS IN THE VIDEO AND PICTURES

The Computer Vision models developed by ASIMOB are applied over videos and pictures taken from the vehicles that are driving at normal speed along the roads. The images taken from the vehicle have the same perspective as the driver. Contrary to the human eye, which cannot focus on several elements at the same time, the Computer Vision techniques allow the identification of several elements at the same time, as well as the measurement and analysis of all of them, applying different techniques. In the case of the analysis of the pavement, with a human eye spectrum camera, in only one frame, several irregularities can be measured in length and width, and colours can be analysed to interpret the defects. To make a more comprehensive inspection at the same time, other non-human eye spectrum analysis can also be applied, using other cameras.

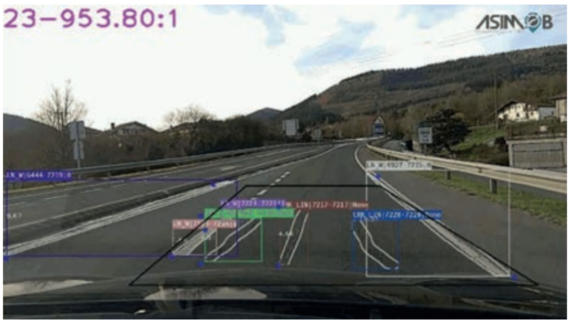

Figure 3. Computer Vision model detecting the irregularities in the pavement.

Nowadays the hardware has not limit comparing with the human eyes and the Computer Vision

training can be adapted to the needs and requirements. The format and features of the cameras can be selected depending on the requirements of the elements under inspection.

The analysis of the defects does not finish with the Computer Vision model. The same defect is

detected in several consecutive frames. A post-processing of the results of all the frames of the video will allow the calculation of the dimension of the irregularities and will perform the classification of the irregularity by type. Thanks to this post-processing each irregularity can be placed on the map, from the exact starting point to the exact end point, with information about the size and classified by type.

THE APPLICATION OF THE MF-89 METHOD WITH COMPUTER VISION TECHNIQUES

Originally, the MF-89 methodology suggests 3 ways to apply the data collection: on foot, from a vehicle or on the basis of photos. In the case of collection on the basis of photos, the procedure suggests the collection of the pictures by cameras but, then, the analysis is applied manually, using a software. The application of Computer Vision models, the automatic post-processing for the classification, and application of the weighting formulas, and the application of geospatial data, will allow a complete automatic application of the methodology MF-89, thus a systematic and very fast calculation of the index for each (sub) section.

Which are the steps from the Computer Vision model to the final Global Index (I_G)?

Each type of irregularity is defined in the methodology MF-89 with the following parameters:

- Identification of the surface: cement concrete, bituminous concrete and modular elements.
- Code for the type of degradation
- Degradation to encode
- Weighting: from 0 to 1 depending on the severity of that type of degradation
- Footprint: vectorial graphic explaining the impact.
- Encoding threshold to evaluate depending on other damage.

Dividing the degradations by type, the percentage of the section affected by each degradation is calculated on the basis of a formula (Pdis) and the final visual index is calculated weighting each type:

$$I_V = \max(0{,}90 - \Sigma_{dis}\, w_{dis} \cdot P_{dis}\ ;\ 0{,}00)$$

I_V = indice visuel pour la gestion des routes selon la systématique du CRR
dis = dégradation (*distress*)
Σ_{dis} = somme de toutes les dégradations observées
w_{dis} = poids d'une dégradation constatée
Pdis = pourcentage de la sous-section de route endommagé par une dégradation constatée

Poids des dégradations pour les revêtements en béton bitumineux

	Fissure longi-tudinale	Fissure transver-sale	Faïençage	Orniérage	Affais-sement/ Flache	Dégradation de bord	Nid de poule/ Pelade	Dégra-dation commune	Plumage/ Ressuage
w_{dis}	0,60	0,60	0,70	1,00	0,50	0,50	1,00	0,25	1,00

Figure 4. IV formula and example of weighting for bituminous surface.

Finally, each inspected sub-section is assigned a calculated visual index (IV). A high visual index indicates a subsection in apparent good condition (few encoded damage and/or low weight) and vice versa for a low visual index. The visual index therefore serves as a first analysis to classify all the sub- sections breaking down the road network based on its surface condition.

According to the system of the CRR (MF-94), two other indicators are defined: the structural index (IS) and the Global Index (IG). Like the visual index (IV), these two indicators display values between 0 and 0.9 and are calculated using simple formulas.

Based on these indexes, from 0 to 0.9, heat maps can be created to visualise the needs of road rehabilitation and facilitate decision-making with a comprehensive global overview.

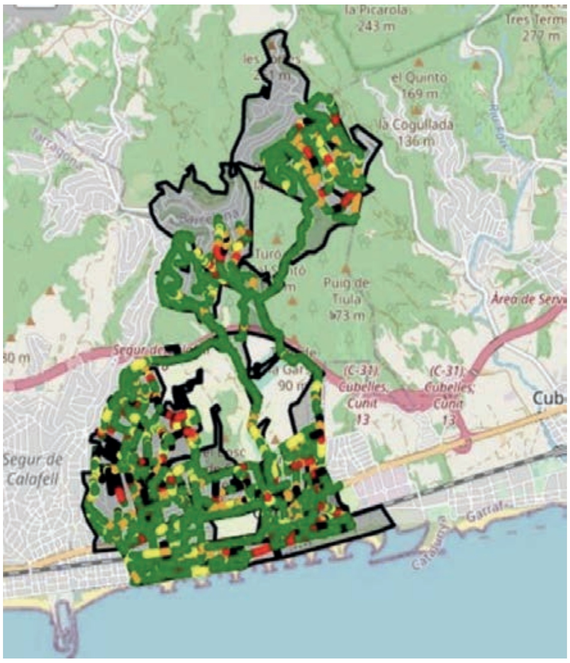

Figure 5. Heat map, according to Global Index (IG), on basis of Computer Vision techniques.

Examples of application of this methodology with solution developed by ASIMOB.

The application of Computer Vision techniques for road surface inspection is better performed lane by lane. The Computer Vision models can adapt to different ways of working but, as explained in MF-89, the lane lines are reliable limits to understand the impact of the defects. That means that the vehicle that takes the images must drive along all the lanes during the inspection.

The solution developed by ASIMOB is already prepared for controlling the number of lanes and subsegments, and there is a tracking tool to visualise which roads have been completely inspected and which one are still left, at almost real time.

As the driver must not be an inspector, the solution can be used by any driver, in any vehicle. In fact, this solution has been used on board of police vehicles, buses or bicycles, as all the collection and upload of images is totally automated, and the driver is not disturbed or distracted.

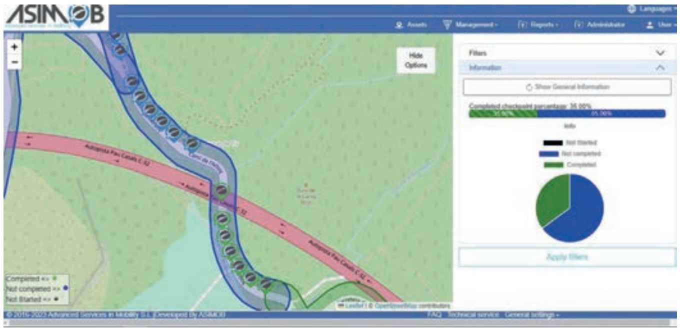

Figure 6. Check points to cover all the lanes and the existing directions.

Although the criteria applied by CRR in Belgium (explained in the table of the Figure 2) are technically optimal, sometimes the thresholds can be adapted in order to adapt to different situations. They can be adjusted depending on the country or the general state of the roads in a region, to avoid the result of the heat map all in red or all in green.

By zooming in on the map, the specific information of each segment can be accessed and the video of the last time the vehicle took images can be watched in order to obtain information about the context.

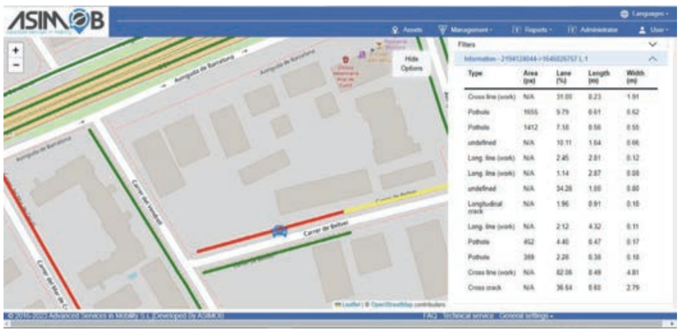

Figure 7. Detailed information of each (sub)sector.

Thanks to a post-processing method, a virtual aerial view can be obtained, for a better analysis by the technical experts. Additionally, other information provided by sensors on board of the vehicles can be also used to complement the visual perceptions.

Figure 7. Virtual aerial view of s street of Mwadrid.

RELEVANCE OF THIS METHODOLOGY COMPARING WITH OTHER METHODS

Comparing with PCI score applied in US and the recommendations applied in Spain, the MF-89 methodology developed by CRR in Belgium is a more comprehensive methodology that includes the complete description of the parameters (weighting, types of defects, surfaces…) that are required to program an automatic evaluation system.

This complete description of the parameters is essential for the training of the Computer Vision models and the development of the formulas for the final score.

In the same way as The Road Authorities that have not developed this kind of procedures depend on the parameters learned by the inspectors in the trainings and their personal criteria, hardly homogeneous, when interpreting the road. But the Computer Vision models need very clear instructions to evaluate the parameters and always apply a unified criterion. The advantage with

Computer Vision models is that the criteria for the evaluation of all the roads will be homogeneous.

As explained in the introduction of the MF-89 methodology, this method is not applied for the drains, the cycle paths, sidewalks, etc. The method would need adjustments to be applicable in those surfaces but, using Computer Vision techniques, only a clear definition of the method is required. And the application of the solution provided by ASIMOB is easy to be installed on board of bikes or scooters.

Another important clarification is related to the need to use different Artificial Vision models and cameras with different characteristics depending on the environment in which these methods are to be applied. The Computer Vision model should not be the same on a highway as on an old street in a city.

In the same way that a human inspector would apply different criteria in one place and another, for each place a different Computer Vision model (or the same model but post-processed with different criteria) will be required.

CONCLUSIONS

The visual inspection methodology developed by CRR in Belgium is a very complete method to perform visual inspections by humans. Thanks to the clarity of the explanations of the applied criteria, this methodology can be translated to Computer Vision models, post-processing methods and formulas. Compared with the frequent trainings required by humans in order to ensure the homogeneous application, the Computer Vision techniques only require one training. The homogeneous and reliable application of the methodology is ensured with a solution that also controls the roads where the vehicle circulates.

The solution provided by ASIMOB for the visual inspection of the pavement covers all the steps required by the MF-89 methodology and other functionality that ensure that the methodology is

applied correctly and in homogeneous way. The solution can be installed on board of any vehicle, so full application in all the road network is easy and fast.

For Road Authorities out of Belgium, the methodology MF-89 is a good example to follow. Depending on the place, some criteria and thresholds should be adjusted, but the basis of this methodology and the details of the parameters that must be taken into account for the process automation, works for any authority.

Once this methodology is implemented, the combination of the results of these visual checks with other checks based on sensors, radar or lidar, will be much easier and more effective.

KEYWORDS

Pavement Index, Computer Vision, Road Safety

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