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Discussion

Road marking assessment using digital image analysis

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This paper makes a valuable contribution to our understanding of how one of the required properties of road markings could be assessed automatically from images of the road surface. We are pleased to have been of assistance to the project by providing the images used. In fact the thanks should be extended to the Highways Agency who funded the development of the prototype line scan image collection which, when fitted to the TRL's high-speed survey vehicle, provided the images shown in the article.

With respect to the analysis technique discussed in the paper, we are concerned that some of the techniques proposed may not give sufficiently reliable results when assessed against current manual surveys of the road markings rather than the laboratory comparisons described in the paper. For example, one aspect of the method appears to assume that the erosion of a line is totally symmetrical. If this is not the case then the method will clearly overestimate the degree of erosion. This comment is based on extensive experience of the problems of monitoring the characteristics of road markings. Over the period 1992 to 1995 we, at TRL, carried out a comprehensive study for the Driver Information and Traffic management Division of the, then, Department of Transport. In this project we developed or adapted techniques for measuring, at traffic speed, the required properties of line markings, including erosion, spread, retroreflectivity, luminance and skid resistance. This led to a specification for a prototype traffic-speed road marking measurement system.[1] During the development we carried out extensive trials of the equipment including measurements at traffic speed and interpretation of the white line erosion of an 80 mile section of the M4. This illustrated the enormous benefits that automated systems could deliver to the highway manager.

Authors' reply

We welcome Mr Ferne's discussion contribution to our paper and the interesting points he raised. These concern firstly the use of image analysis for the evaluation of the road surface features, secondly the accuracy of the results derived from the analysis and thirdly the efficacy of a computerised process in the assessment of the erosion compared to a manual system.

The development of a digital image analysis process for road markings at the University of Birmingham was a consequence of research carried out for the assessment of cracking on road surfaces. In both cases, the PhD-oriented research was carried out to produce a proof-of-concept prototype system which investigated a number of issues related to image acquistion, storage and analysis. For the work on road markings, emphasis was put on to the analysis of the images and the results clearly showed the need to use a computerised system because of the benefits accruing therefrom. These include the versatility of the digital analysis to enable the erosion of a road marking to be measured together with other road marking characteristics in addition to pavement defects. Details of this investigation may be found elsewhere.[2]

As far as the accuracy of the analysis is concerned, it is not consistent with the examples given in the paper to suggest that the techniques proposed assume that the erosion of an analysed road marking is symmetrical. On the contrary, the majority of the road markings analysed by the system in fact had been eroded in an asymmetrical manner. Clearly neither of the two markings presented in Fig. 1 in the paper is eroded symmetrically, yet the system was able to measure their erosion to a high degree of accuracy (see Table 1).[3]

As described in the paper, the measurement of erosion requires the area of road marking remaining on the road surface and the original, uneroded (or 'ideal') area to be determined and compared. Of these two distinct tasks, it was believed that the former would be the most challenging to achieve using image processing techniques. Consequencly, considerable research was undertaken to select, design, program and implement appropriate techniques for this task. As a result of this research, two techniques, namely sub-image thresholding and post-segmentation enhancement, were selected and reported in the paper. These techniques were chosen as they performed their tasks accurately and independently of the shape of marking or the amount and symmetry of the erosion present.[2]

Concerning the task of determining the 'ideal' area of road marking, it was recognised that the methodology described may not be suitable in all cases and would require further research to perfect.[2,3] Nevertheless, the methodology, despite its obvious limitiations, did allow the erosion of the *asymmetrical* road lines analysed in the given data set to be determined accurately and has enabled a proof-of-concept of the system to be established.

To improve the proposed methodology of determining the area of the 'ideal' marking present in an image, several alternative approaches may be adopted. One such, as yet not fully tested, approach involves using a database of information containing the 'ideal' areas of road markings together with information about the location and orientation of the captured image to determine the 'ideal' amount of road marking in the image.

As for the efficacy of the computerised process for the assessment of the erosion proposed compared to a manual system, the authors strongly believe that the use of a computer program eliminates the subjectivity of the measurements found in manual methods. Indeed, as in the crack analysis system, the objective of the computerised method established was to produce a system with increaed repeatablility and reproducibility. To this end the research for the development of an automated road marking assessment system included a statistical analysis which clearly showed the superiority of the computerised system over that carried out manually. This is in agreement with similar findings both from the crack analysis work and work on road marking analysis carried out elsewhere.[4,5]

Highways Agency",5,1,0>S. Xavier, *Highways Agency*

The paper makes interesting inroads into video-imaging and analysis. It is a very useful contribution to the state of the art and science of road markings. The paper refers to 13 road markings used as a data set. It would have been useful to know the diagram numbers of the road markings to Schedule 6 of the Traffic Signs Regulations and General Directions 1994. Also, perhaps, the authors can comment if the larger road markings given in the schedule could be video-imaged and turned into a sort of 'as-built' drawings.

To ensure the highest-quality standards at reasonable cost, the Highways Agency's Specification for Highway Works calls for Type A certificates to BS 3262. Among other requirements, that also include a degree of erosion measurement at a two-year life at the certification stage–that is, not exceeding a wear index of 35. That means only durable materials such as thermoplastic or preformed tape, which could show acceptable standards after two years under live traffic conditions on the A1 site at St Neots, Cambridgeshire, can be used. The test supervisor of this important quality proofing work over the years has been the British Standards Institution. The British Standards BS 3262, 6044 and 7396 (not 7936) are now superseded by a raft of European Standards: BS ENs 1423, 1424, 1436, 1790, 1824 and 1871. The new road trial site opened in 2000 is the Six Mile Bottom site on the A11, also in Cambridgeshire. The British Standards Institution continues as the supervisor of the new road trials site.

Practising highway engineers would be keen to know what really happens to the road markings after the two-year period assessed by the Type A certificate, up to the point when it would be essential to replace them. I believe it is at this stage in the life of a road marking that the use of high-speed monitors carrying digital-imaging systems could become very effective for condition surveys. A further mobile instrument that could be added to the system to measure retroreflectivity and skid resistance would be very much welcomed, along the lines of the preliminary research work carried out by TRL some time ago. Retroreflectivity measurements could only be an initial indicator of the state of the lines unless the lines are properly precleaned. Some engineers feel grip testers are a problem with road markings with in-line road studs. Perhaps the authors could comment on these difficulties and suggest ideas for further research.

There are a few factual errors in the way of reference to the practising engineers' maintenance management tools. There are in fact three documents used by the Highways Agency for the maintenance of trunk roads and motorways by its 20 agents and eight DBFO contractors. One is the Highways Agency's National Standard, TD 26/86 on the maintenence of road markings.[6] This is under review and any one interested should contact the Highways Agency for further information. The other document is the *Trunk Road Maintenence Manual*.[7] It has up-to-date information on maintenance not only of road markings but also road studs used in the gaps of road markings (i.e. in-line) or adjacent to them. Yet another document is the *Routine Maintenance Management System*,[8] which is geared to computerised record-keeping and retrieval. The HASS document referred to in the paper is now superseded by the STANSPEC and is published by the Road Safety Markings Association.[9] The e-mail address for the contact at the Highways Agency is sydney.xavier@highways.gsi.gov.uk/

Authors' reply

We would like to thank Mr Xavier for his useful contribution to the discussion on the assessment of road markings using digital-image analysis. In reply to his question regarding the diagram numbers of the road markings to Schedule 6 of the Traffic Signs and Regulation General Directions 1994, all markings analysed were of type 1013.1d. Certainly the technology exists to capture the larger markings described in the Schedule for the purposes purported by Mr Xavier. When so doing, it would be necessary to consider the desired quality of the images in terms of their pixel and colour resolutions as these would affect both the type of equipment used to capture the images and the media on which they could be stored.

Mr Xavier raises a number of important issues regarding the conditions under which road markings should be measured to determine their performance. In normal conditions, road markings are likely to be dirty and, in the UK at least, wet for a large part of the year. However, measuring the performance of road markings under such conditions may not give accurate results as it is known that the retroreflectivity, luminance and skid resistance of a road marking change when the marking becomes dirty and/or wet.[2] Consequently, where accurate measurements of the performance of road markings are required, the road markings should be cleaned (and dried). An alternative approach, which would require further research, would be to attempt to relate the performance characteristics of road markings as measured when the marking is dirt or wet to existing road marking standards to determine an acceptable level of serviceability.

Finally, we thank Mr Xavier for providing an up-to-date list of the new European Standards for road markings and the documents currently used by the Highways Agency for the maintenance of road markings. At the time of the research, the

European Standards were still at the draft stage and thus it was felt inappropriate to comment on their requirements.

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