Development of a Presence Assessment Tool for Iowa's Pavement Marking Management System

Final Report
May 2011

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Center for Transportation Research and Education

IOWA STATE UNIVERSITY
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16. Abstract

Pavement marking quality is normally assessed using presence, or how much of the pavement marking material remains on the pavement, which provides day time guidance, and retroreflectivity, or how visible the pavement marking material is at night. Both of these two measures determine pavement marking durability. This report discusses the use of image processing techniques to assess pavement marking quality.

Images of pavement markings are processed using a number of operations. Image segmentation is the process of assigning the set of image pixels to regions having common characteristics. The proposed system tries to segment images of white or yellow pavement markings into foreground (marking) and background (pavement) parts. The images are then processed to determine pavement marking presence in an objective and consistent manner. The resulting assessment is critical to the implementation and development of a pavement marking management system and quality control/assurance processes.

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DEVELOPMENT OF A PRESENCE ASSESSMENT TOOL FOR IOWA'S PAVEMENT MARKING MANAGEMENT SYSTEM

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The authors would like to thank Iowa Department of Transportation (DOT) and the Midwest Transportation Consortium (MTC) for sponsoring this research.

INTRODUCTION

Pavement marking quality is normally assessed using presence, or how much of the pavement marking material remains on the pavement, which provides day time guidance, and retroreflectivity, or how visible the pavement marking material is at night. Both of these two measures determine pavement marking durability.

This report provides a brief summary on the development of a tool to provide consistent, repeatable, and quantifiable pavement marking presence measurements. The term presence, here, refers simply to the amount of pavement marking material remaining on the roadway as illustrated in Figure 1.

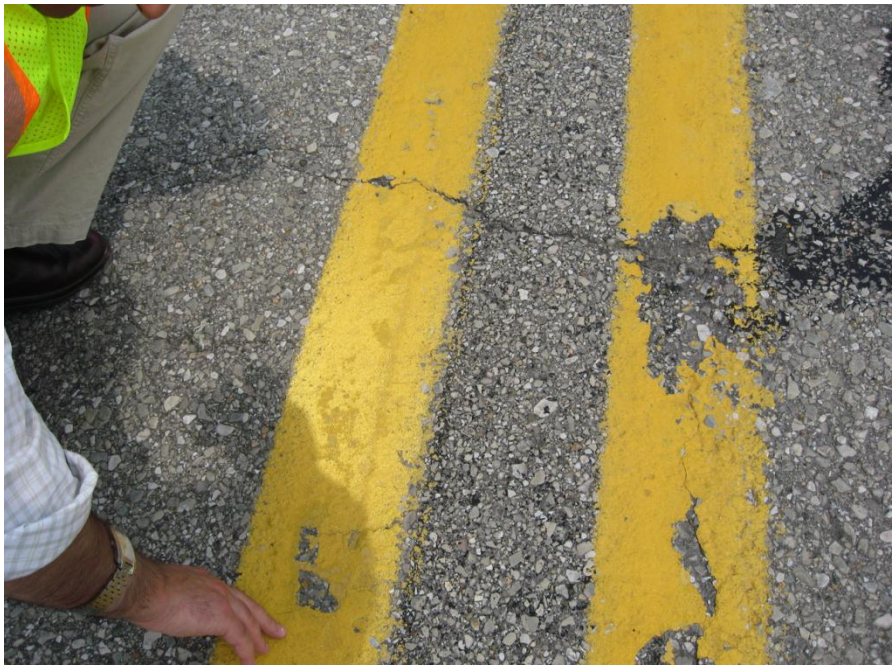

Figure 1. Pavement marking damage

BACKGROUND

Those white and yellow lines on the roadway play a big role in guiding and providing safety to the traveling public. Agencies in the US are keenly aware of the costs and efforts associated with maintaining these markings in an acceptable condition. As an example, the Iowa and Washington State Departments of Transportation (DOTs) each spend approximately $2 million and $10 million, respectively, on annual pavement marking installation and maintenance *(1, 2)*.

"Today, delineation is an established component of the highway system. The question is no longer one of whether delineation is effective, but rather one of how to provide the best system of delineation for the least cost" (3).

Pavement marking conditions are noticed by motorists as was revealed in a recent Iowa DOT survey, which found that motorists ranked pavement marking visibility as one of the key criteria in rating the quality of the roadway network *(4).*

Given the drain on resources, demands from the public, and an impending Federal Highway Administration (FHWA) minimum pavement marking retroreflectivity ruling, many agencies are revisiting what is considered to be a marking with an "acceptable" condition.

An acceptable pavement marking to the motoring public is usually defined using two simple criteria: "How well can I see it during the day" (presence) and "How well can I see it at night" (reflectivity). Among technical groups, these attributes are described as "daytime presence" and "nighttime reflectivity."

Agencies are beginning to place a high value on managing pavement marking performance based on these criteria. As an example, both the Iowa and Minnesota DOTs are using pavement marking management systems on a statewide basis to keep markings above "acceptable" set thresholds *(5).* Such a system allows the agency to monitor marking conditions and place new materials only where needed. These efforts have been well received by agencies and the public and have reduced costs and improved quality. Figure 2 shows an example of the Pavement Marking Management Tool (PMMT) data from the Iowa DOT.

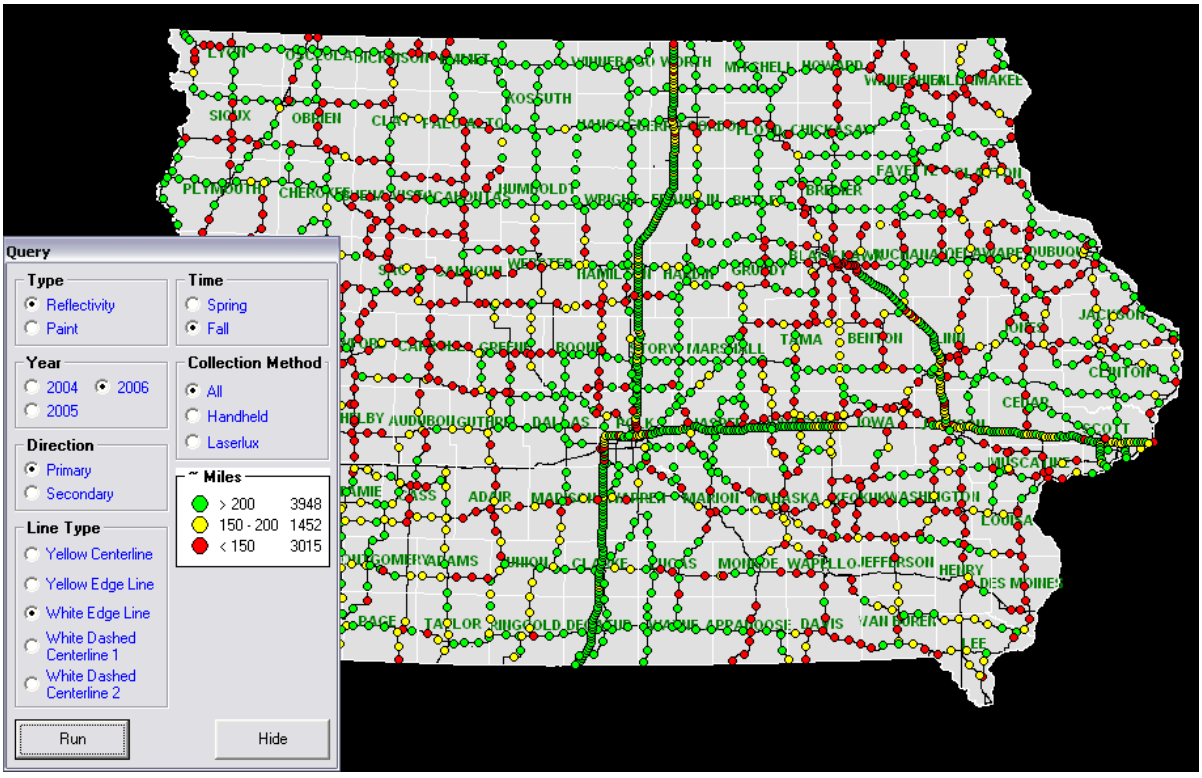

Figure 2. Pavement Marking Management Tool map showing the retroreflectivity of pavement markings

STATE OF PRACTICE

As with any asset management system, the key to effective decision making begins with a good assessment of current conditions. The state of practice for pavement markings involves measuring nighttime visibility or retroreflectivity objectively, without being influenced by personal feelings, and measuring daytime visibility subjectively, based on somebody's opinions or feelings, rather than on facts or evidence.

Specific to reflectivity, a number of devices are on the market that, with little training, provide quick, objective, repeatable, quantifiable, pavement marking condition measurements. The measured condition is also referred to as the pavement marking retroreflectivity. As an example, a new white or yellow painted line typically measures 400 and 250 millicandella (mcd), respectfully. (The unit mcd is short for millicandella with actual units being millicandella per meter squared per lux.) Figure 3 shows a typical handheld retroreflectivity device in use.

Figure 3. Measuring retroreflectivity using the a handheld device (LTL-X)

In contrast, determining daytime presence is done through a subjective processs, where someone's opinion regarding the amount of marking material remaining on the roadway is obtained. This judgment may be assisted through the use of a calibration panel, photo, or personal experience; However, there are currently no quick and convenient "machines" on the market to perform this task.

Especially within snow plow states, like Iowa, where each spring significant portions of the markings may be damaged, there is a demand for the ability to measure presence in a repeatable, more consistent, and non-subjective way. Objective presence assessments, in combination with retroreflectivity conditions, will facilitate managing markings for both their daytime and

nighttime performance. This combination will enhance decision making in terms of marking installation and maintenance, overall investment, safety, and the use of new products and innovation.

To be clear, presence can be defined in terms of both the amount of material remaining *and in the fading or color change of the material*. This report does *not* address color issues, as objective methods currently exist to obtain these measurements.

The focus of this research was to develop an objective, consistent, repeatable, and quantifiable pavement marking presence tool, which would provide the percent of material remaining on an in-service pavement marking, using digital images of the markings and image analysis software for determining presence.

TOOL DEVELOPMENT

The research team established a number of short- and long-term goals for measuring the amount of pavement marking remaining on different highway segments. This report summarizes the short-term findings. Although this report is on markings on concrete roadways, the tool has been set up to accommodate a variety of pavement surface types, including asphalt and seal-coated roads.

All calculations are based on a digital image, taken with a camera, of the subject pavement marking, along with the identification of the pavement surface type. From this, the program provides the calculation for the percent paint remaining.

Image segmentation is the process of assigning the set of image pixels to regions having common characteristics. The proposed system tries to segment images of white or yellow pavement markings into foreground (marking) and background (pavement) parts. The system then objectively reports the presence by calculating the percentage of white and yellow paint to the total image area. The system assumes that the image being processed complies with the general rules specified by the DOT protocol (image resolution, image dimensions, and the number of images taken for a specific segment length) used for detecting presence.

The system consists of three major stages: image enhancement, clustering, and analysis (See Figure 4).

In the first stage, image enhancement, a number of filters are applied to maximize the probability of separating the white and yellow color markings that we intend to distinguish from the gray concrete. The filters include histogram equalization in the red-green-blue (RGB) color space, as well as color separation filters in other color spaces. The different values for the used filters were chosen empirically.

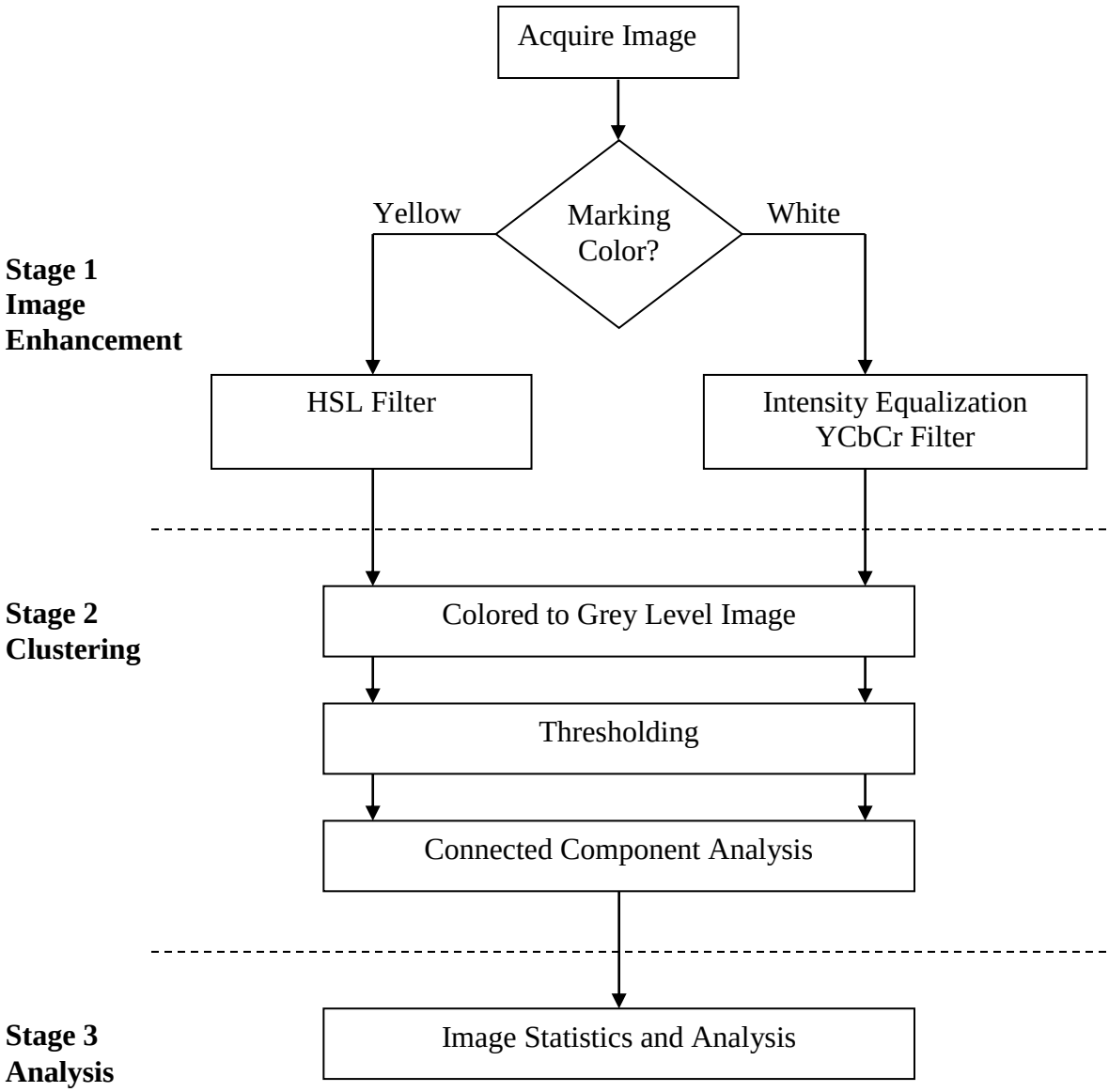

Figure 4. Three major stages for calculating percent paint remaining

The second stage, clustering, is independent of the marking's color. It takes the output image of the image enhancement stage and performs the following operations:

Gray-level conversion: where each colored pixel in the image is represented by a single value in the range of 0-255.

Binary image conversion: where every pixel in the gray-level image is labeled to either a foreground or a background pixel, based on the value of the pixel compared to a threshold, which was determined empirically (threshold = 50).

Connected component analysis: where the different adjacent pixels with similar labels are grouped into one component.

The third stage, analysis, collects statistics of the different connected components (their count and size) and reports the percentage of foreground (white or yellow paint) to background (gray) pixels.

CALIBRATION

The tool was tested against different combinations of known composition. Figure 5 shows a combination of processed black and white squares (white area shown in red for contrast), which the tool accurately showed 50 percent remaining. More calibration is needed to ensure accurate and consistent determination of the pavement marking material remaining.

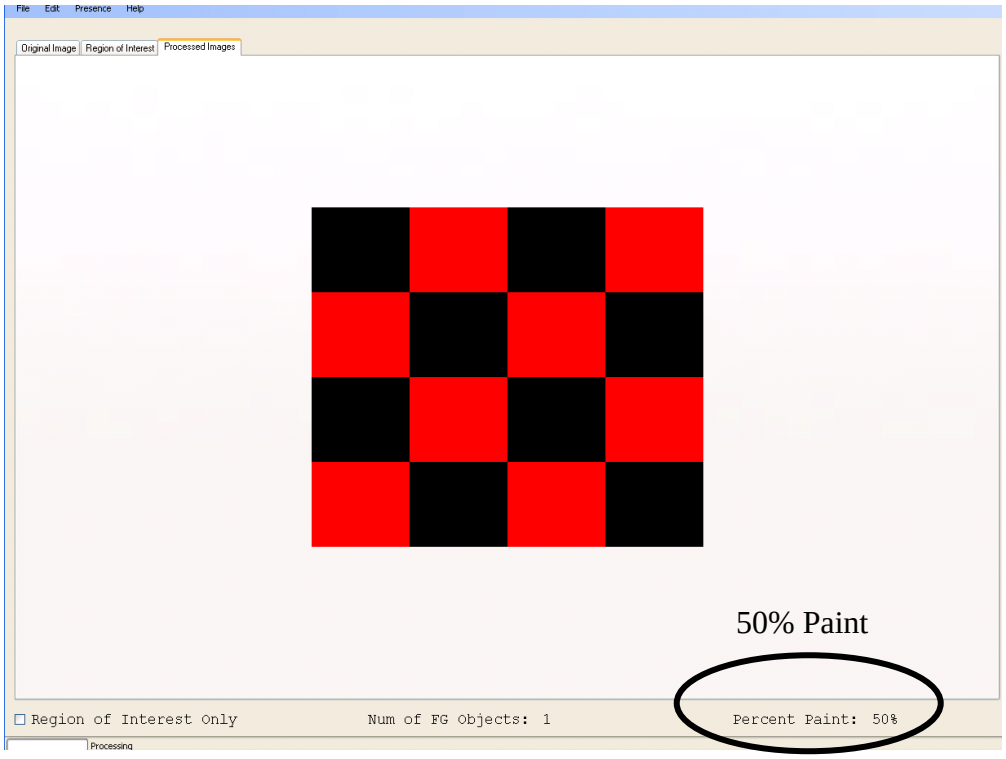

Figure 5. Calibrating the image processing tool

EXPERIMENTAL RESULTS

We applied the proposed system on a number of color field images of white and yellow markings on concrete. Figure 6 shows sample images where the tool was used to analyze white paint on an asphalt surface. The upper portion of the photo shows the original image. The colors on the lower image show processed paint by color. The color is used to provide feedback on contiguous areas of foreground material.

Although there is room for improvement, comparing the two images reveals very close pattern recognition of paint material. Viewing the upper image, can you estimate there is 50 percent paint remaining? And, would two people agree based solely on their own judgment? Our findings have shown that the tool greatly reduces subjectivity and provides a much needed repeatability to the analysis of presence.

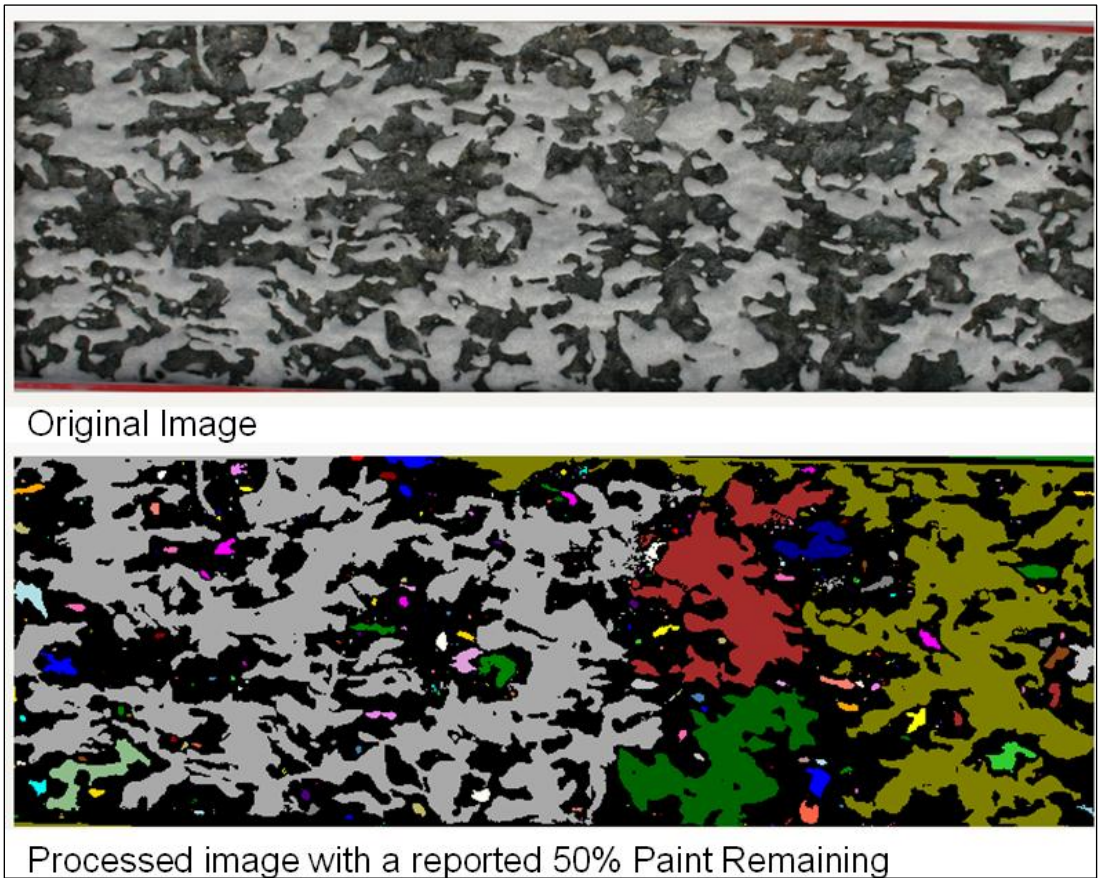

Figure 6. Methyl methacrylate (MMA) pavement marking processed using the presence tool

SUMMARY

This research enhances the ability to analyze the presence of in-service pavement markings. This innovation comes through applying well-established capabilities developed with image-processing technologies. These initial findings have produced a repeatable, objective, and efficient method to evaluate pavement marking presence.

Further research and development are needed to add the different pavement types, determine the minimum image resolution needed for accurate and repeatable measurements, and improve the user interface to allow for further enhancements of the results by identifying and fixing false positives and false negatives.

Objective presence assessments, in combination with retroreflectivity conditions, will facilitate managing markings for both their day and night performance. This combination will enhance decision making in terms of marking installation and maintenance, overall investment, safety, and the use of new products and further innovation.

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