DETERMINATION OF PAVEMENT CRACKS FROM PHOTO IMAGERY TAKEN BY A SLIT CAMERA

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Outline

This study was made to propose a method for automatically detecting cracks in pavement by using continuous photo images of a road surface and to review the possibility of its practical application.

For this purpose, we have developed the following method.

1. By using a super scanner, continous photos of the road surface were scanned and the images were converted into digital data.
2. Next, the density threshold value was established to determine the crack, and then the crack was determined.
   At that time, however, a crack of 5 cm in length or more was defined as a crack.
   After this method has been tried on several types of samples, considering the accuracy of detection of cracks and the processing time by the computer, the possibility of its practical use was sufficiently accepted.

1. Digitalization of the photo image

For detecting cracks and computing the crack rate, values were analyzed. For this purpose, a super scanner was used first to digitalize and convert the photo images into numerical value data. This method is indicated below.

(1) Taking continuous photos of the road surface

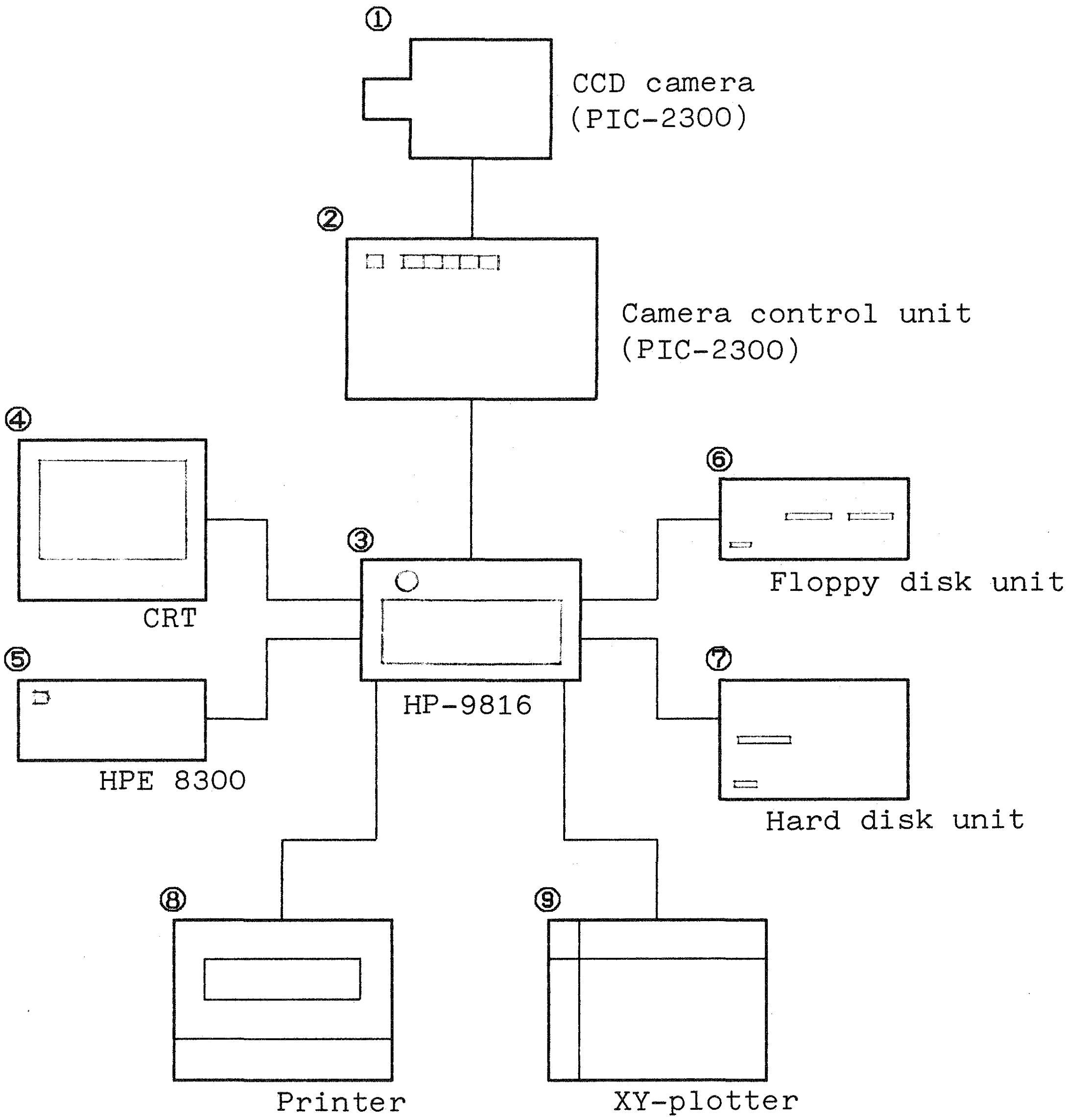
By using an automatic measuring device ROADRECON-70, photos of a road surface were continuously taken on a scale of 1 to 200. At that time, the speed of the measuring vehicle was set at 50 km per hour.

(2) Preparation of digital data

By using a super scanner (PIC-2300), the positive film of the continously taken photo was scanned at 12 micron width, and the photo density of each pixel was measured and digitalized.

At that time, by using a small computer (HP-9816) and its peripheral equipment, the image data were read, processed, and stored in a hard disk unit (storage capacity 20 M byte). The outline of the composition of this equipment is indicated in Figure 1.

Figure 1 Outline of the composition of the equipment



2. Automatic crack analysis system

By using the numerical data of photo images which were obtined as indicated in the above paragraph, cracks were detected and the crack rate was calculated. The outline of this system is indicated below.

(1) Detection of cracks

For detecting cracks, various methods may be considered. From the viewpoint of a practical use and in particular to shorten the computing time, however, a method was sought to establish threshold value based on the photo density and that would determine a possibility for cracks at a value higher than that threshold value and no possibility for cracks below that value.

To de this, since there is a nonuniformity of density on the surface of a photo, this defect must be removed first. Fortunately, since under actual conditions there was a good deal of nonuniformity in the crosswise direction (across the road) and it was practically negligible in the lengthwise direction (the direction along the road), an average density value was obtained in each lengthwise scanning line, and then its relationship with the threshold value was obtained. Table 1 indicates this relationship that has been obtained by using samples (Refer to 3. Experiments).

Table 1 Relationship between average values in the lengthwise line and the threshold values

Average density in the lengthwise line (x)	Threshold values		
	A	B	C
When it is 30 or less ($\bar{x}<=30$)	$\bar{x}+1$	$\bar{x}$	
When it is 31 or more ($\bar{x}>=31$)		$2\bar{x}-30$	$2\bar{x}-31$

A: When all densities of each pixel in the lengthwise line are 60 or less.

B: When pixels in the lengthwise line have densities from 61 to 80,

C: When pixels in the lengthwise line have densities of 81 or more,

Then the continuity of pixels that was judged as having a possibility of cracks was inspected, and in actual practice, those with the length of less than that have been discarded as photo noise.

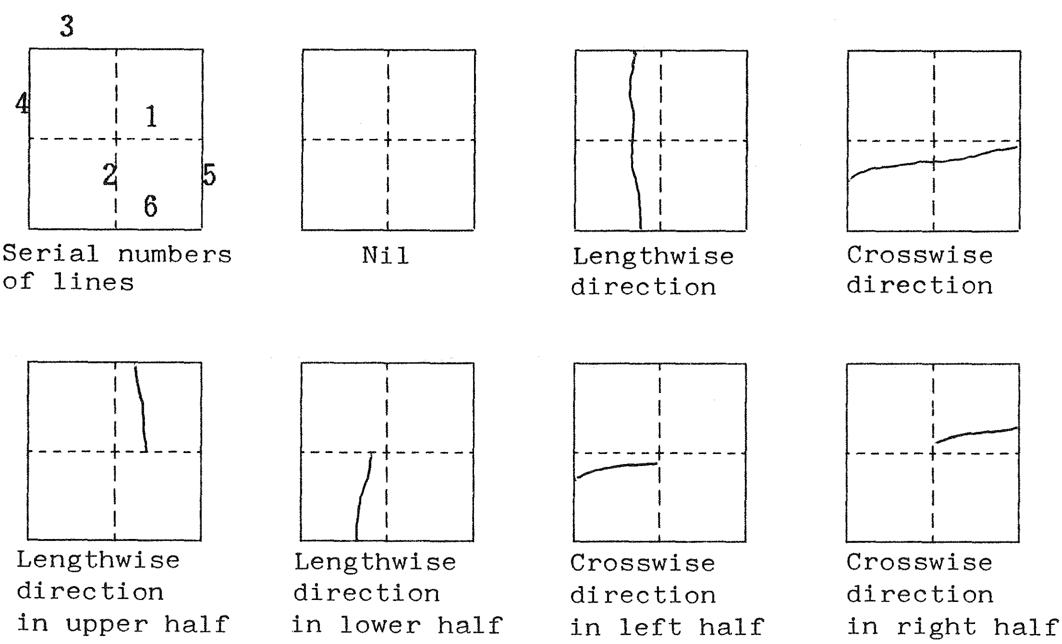
(2) Calculation of crack rate

According to the crack rate calculation methods presently used in Japan, we considered the most efficient method to meet the following conditions.

1) Those with length of 5 cm or more are judged to be cracks.
2) A crack rate is calculated taking 100 meter length of the road as a unit.
3) For calculating a crack rate, a 100 meter long unit area is first divided into 50 cm x 50 cm squares (when the road width is 4 meters the number of squares will be 1600), then each square is inspected for the presence of cracks, and finally the ratio of the number of squares with cracks to the total number of squares is obtained.
   An outline of the crack rate calculating system for a 100 meter long unit area is indicated below.

1) Calculate a crack rate in a 100 meter long unit area.
   1) Divide a 100 meter long unit area (4 meters wide) into 1600 (8 x 200) pieces of 50 cm x 50 cm squares.
   2) By using the method mentioned in the below 2), determine the presence and forms (pieces with only 1 crack piece will be considered linear forms, 2 or more will be considred surface forms) of cracks in each square.
   3) Calculate the ratio of the number of squares where cracks have been detected to the total number of squares, and make it the crack rate.
2) Calculatin of a 50 cm x 50 cm square
   1) Obtain average value of density for each line in the lengthwise direction (lengthwise direction along the road), and determine the threshold value by using Table 1.
   2) Further divide the square into 100 small squares of 5 cm x 5 cm.
   3) Starting from a corner of a large square, calculate the small squares in order according to a specified sequence. At that time, the calculation inside the small square should be performed based on the models in Figure 2, and first, the points with possibility of having cracks should be detected on lines 1 and 2 by using the threshold value indicated in 1).
      If these points have been detected lines 3 and 6 or 4 and should also be calculated. Thus, when the possibility of preseence of cracks has been recognized their continuity should also be checked.

Figure 2 Crack detecting models in small 5 cm x 5 cm squares

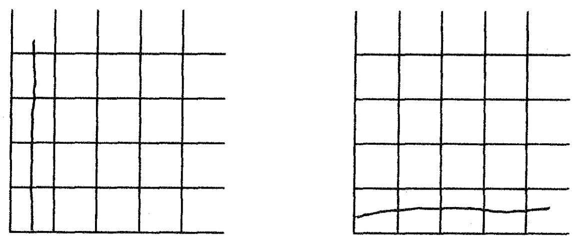


If the points with possibility of having cracks have not been detected on lines 1 and 2 or continuity has not been recognized, then there are no cracks, and you should thus, move to the next small square.

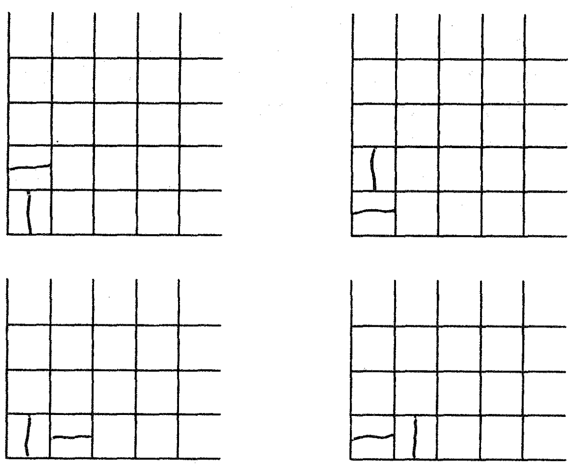
4) When the number of small squares with cracks has been detected which meets the specified number to satisfy the models in Figure 3, judge their forms and complete the calculation, and then move on to the next 50 cm x 50 cm square.

Figure 3 Models for judging crack forms

1. Linear forms
   (1) When a crack is in one small square,
   (2) When a crack is in same direction in two or more continuous small squares.



2. Surface forms
   (1) When cracks with different directions are found in two continuous small squares,



   (2) When cracks are found in two non-continuous small squares)regardless of the direction of cracks).

3. Experiments

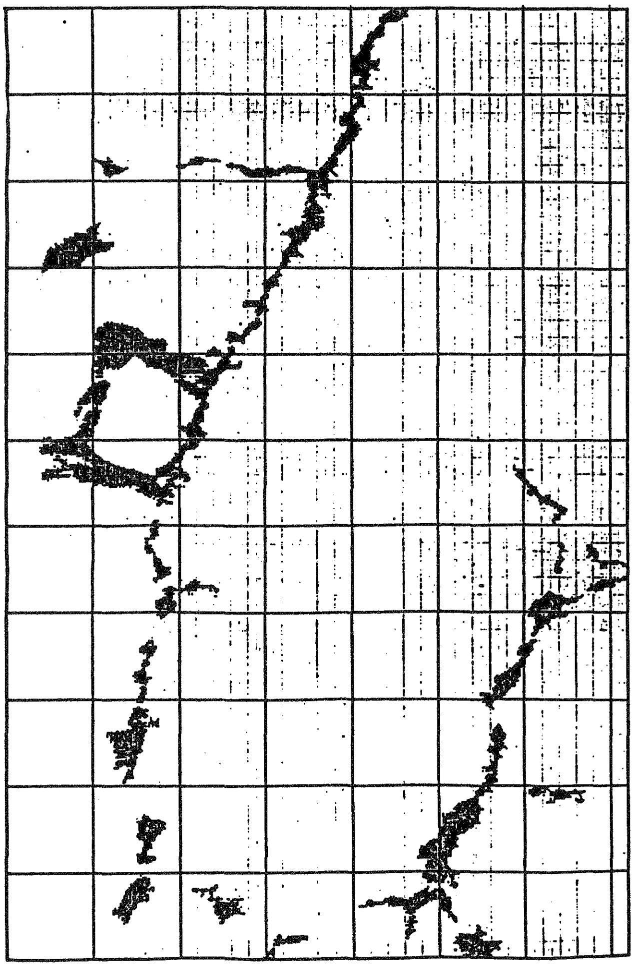
From amon the continuous photos, six positions with different road surface conditions have been selected, and two types of scanning, of 25 microns in width and 12 microns in width, have been performed and reviewed by comparison each other.

In the case of the 25 micron width, 1 pixel in size corresponds to the actual size of 5 mm, and in the case of 12 micron width, 1 pixel corresponds to about the size of 2.5 mm.

As a result of these experiments, it has been found that 25 micron scanning is incapable of determining a 1 mm wide crack but that the 12 micron scanning is suitable for this. However due to the capacity of the scanner, experiments to scan widths of less than 12 microns could not be performed, but it was presumed that when the scanning width became so narrow, since the volume of light per 1 pixel would become so little that the judgment of cracks would become even more difficult.

Figure 4 indicates an example of a crack detection performed with width of 12 microns. When the accuracy of the crack detecton was indicated by the ratio of detected crack length to the total length of the cracks it was 90% on average.

Figure 4 An example of crack detection



Computing time for the crack rate calculation was about 25 minutes when using the equipment indicated in Figure 1, and for a unit area of 100 meter in length and 4 meter in width. This was the result when the old type equipment was used, however, if the equipment is appropriately composed under the present conditions the computing time should be shortened to about 1/5 - 1/10 of the above mentioned time.

Conclusion

As mentioned at the beginning this study sought to review the possibility to automatize the crack analysis, and from the viewpoint of the accuracy of crack detection and the speed of crack rate claculation, etc., we believe this method can be adequately offered for a practical use.

When using continuous photos of the road surface, however, since there are items other than cracks such as pot-holes and overlays, etc. that must be read and judged at the same time, it is necessary to carry the study forward to the automatic judging of these, and develop a system that can analyze these items as well as cracks simultaneously and efficiently.