Coding and Analysis of Cracked Road Image Using Radon Transform and Turbo codes

G.Bhaskar[1], G.V.Sridhar[2]

[1] Post Graduate student, Al Ameer College Of Engineering, Visakhapatnam, A.P, India
[2] Associate professor, Al Ameer College Of Engineering, Visakhapatnam, A.P, India

***Abstract*—** The image processing technology has been widely applied to cracked road image analysis. This paper presents a method for automation of crack detection, classification and evaluation of cracked roads. Besides, the constraints on bandwidth, power, and time in many image communication systems prohibit transmission of uncompressed raw image data. Compressed image representation, however, is very sensitive to bit errors. In this Paper, the image is compressed by using bit plane slicing and the same is turbo encoded. The crack detection part of the algorithm is built upon the wavelet transform and the evaluation part is considered in the Radon transform domain. The very strong property of the Radon transform is the ability to extract lines from very noise images. Hence, it is concluded that the algorithm in this paper to identify the cracks on roads is combined with turbo codes, Bitplane Slicing results in an excellent way of image compression along with reduced bit error rate even in noisy channel transmission.

Index Terms— Radon transform, Wavelet transform, Bit plane slicing, Turbo encoding.

I.INTRODUCTION

The detection of cracks and other degradations on pavement surfaces was traditionally done by human experts using visual inspection while driving along the surveyed road. To overcome the limitations of the manual scheme, an automatic crack detection and classification system is proposed in this paper to both speed up and reduce the subjectivity of the process.

Automatic detection of road cracks has been a hot topic since it reduces economic loses. It is not easy to get efficient detection algorithms because of complexity, diversity of pavement images and pavement distress's weak information. Since a huge amount of data is expected to be collected, it is desirable that a rapid screening of pavement surfaces can be performed in real time to detect the existence of distress and to evaluate only those images with distress. The previous proposed methods like histogram projection, localized thresholding are not completely automated and may require human interaction to set certain seed parameters. And they can produce false detection when it is applied to real pavement images. While focused on the severity of cracks, crack classification in terms of sealed or unsealed, was not performed. Moreover, the system cannot detect multiple cracks within an image.

Application of a channel code is required before transmission of data over noisy channel for increased reliability. In order to encode an Image they are represented in digital format in a wide variety of ways for comfortable processing and transmission using Digital Techniques. The main aspects to be considered during transmission of an image are Bandwidth requirement and the effect of noise during transmission. But, compressing an image may lead to the degradation of its quality and at the receiver conventional filtering techniques used to eliminate noise may also affect the image. Bitplane Slicing technique is an efficient method of compressing an image and an iterative process of decoding the image using turbo codes, considering the Stochastic Properties and Neighborhood relation between the pixels, results in a better way of image transmission. Turbo Codes make it possible to attain a better bit error rate performance and robust transmission even in a noisy channel transmission. Hence, the image to be transmitted is compressed is converted into binary and then Turbo encoded. Turbo encoding preserves the PSNR of the image even in a noisy environment. This type of system can be adopted for transmission of the image through a highly noisy environment.

II.SYSTEM MODEL

The first part of algorithm in this paper consists of three stages, to analyse the cracks, namely (1) detection ;(2) domain mapping; and (3) classification. A flowchart indicating the sequence is shown in Fig. 1. And the three stages are explained in detail as follows. The second part of algorithm consists of an image to be transmitted (image involved in analysis) is compressed using bit plane slicing and turbo encoded.

A. Crack Detection

In this stage, the true color pavement image is first transformed into a gray scale image. Following this step a discrete 2-D wavelet transform using db2 wavelet is applied to this gray scale image to yield four sub-bands namely, HH, HL, LH and LL. The notion behind this process is to first filter each row followed by a down sampling to obtain two (N X (M /2)) images from an N X M image. Then, apply the filter column wise and subsample the filter output to obtain four ((N/2)X(M/2))images. This will lead to a set of 4 sub-images known as LL, LH, HL, and HH sub bands. The decomposition of an image into four sub bands is represented in the Fig. 2.Finally;

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extended pseudo color matrix scaling is performed on the approximation matrix. A pseudo-color image is derived from a gray scale image by mapping each pixel value to a color according to a table or function. Pseudo-coloring can make some details more visible, by increasing the distance in color space between successive gray levels.

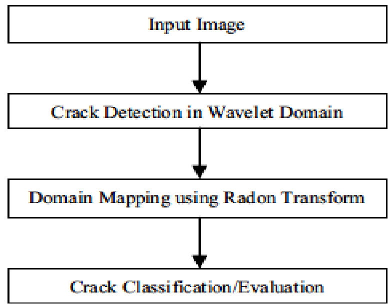

Fig. 1: Flowchart of the Algorithm

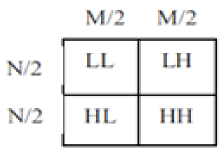

Fig 2. Wavelet decomposition of an image

B. Radon transform

Radon transform utilizes a set of projections at different angles in an image f(x, y). The resulting projection is the sum of the intensities of the pixels in each direction, i.e. a line integral. The result is a new image R (ρ, θ). It can be expressed using the following mathematical formula:

$$R(\rho,\theta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(\rho - x\cos\theta - y\sin\theta)dxdy$$

Where δ (.) is the Dirac delta function, ρ and θ represent the distance to the origin of the coordinate system and the angle of the line, respectively. The Radon transform has the ability to transform two dimensional images with lines into a domain of possible line parameters, where each line in the image will give a peak positioned at the corresponding line parameters. This has lead to many line detection applications within image processing.

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The angle of a crack is defined as the angle between the direction of the crack and the lateral direction of the road. It can be seen that a peak at 90° in the Radon transform indicates a transversal crack on a pavement, and the x coordinate of the peak determines the position of the crack. Similarly, a peak at 0° indicates a longitudinal crack, and a peak at 135° or at 45° indicates a diagonal crack. A peak array is defined as having at least two peaks at a certain angle. If there are two or three peaks at different angles, the cracks are the combined single cracks of longitudinal, transversal, or diagonal types. If there are four or more peaks, one needs to determine first whether they form the patterns. In summary, the Radon transform is applied to the image after crack detection.

C. Crack classification and Evaluation

The process of crack classification and evaluation involves three important parameters, the number of cracks, the position, and the maximum value of the window in the Radon transform. The position includes the angle θ and location x of the window. Peaks in the Radon domain are related to the cracks in the space domain. First, a threshold is needed to segment the Radon transform image to separate the peaks from the non-peak regions. A Peak is defined as 75% of the maximum value of the Radon Transform. After finding all the peaks, a clustering algorithm is applied to merge all the peaks in the same window. A graph of the Radon transform of the image can display some important information as follows:

(1) Number of the peaks may indicate number of the cracks
(2) Degree of projection shows whether it is longitudinal, horizontal or diagonal
(3) Area of the peak determines the width of the crack
(4) Value in the Radon domain means the rough length of the cracks;
(5) Projection position gives the rough locations of the cracks.

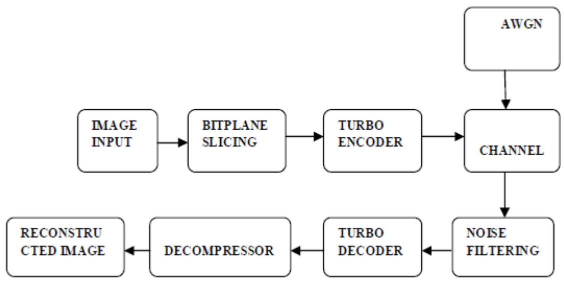

Fig 3.System model

The system mainly constitutes a combination of Image compressing technique and a robust channel encoder. A 2D image which needs to be transmitted is first compressed using bit plane slicing technique. The Compressed image is binary converted. This binary image is now encoded using a parallel concatenated way of channel encoding. The Turbo encoder constitutes a combination of RSC encoders which encode the image. The encode image is now transmitted through a channel having additive white Gaussian noise. At the receiver a filtering technique is used to remove the undesired signals and to reduce the effect of noise on the signal. The received signal is then Turbo decoded. The processing of the resultant using decompressor regenerates original resembling image. The main advantage of the system is to compress the image using a highly sophisticated way and to make it much robust towards noise using Turbo codes.

III. BIT PLANE SLICING/RE-ASSEMBLING

Highlighting the contribution made to the total image appearance by specific bit plays an important role in compression of an image. This is the basic principle involved in Bit plane Slicing. In digital image representation each pixel is represented by number of bits. The number of bits required to represent each pixel depends on the grey levels identified in the image. The number of bit planes is equal to the number of bits represented for each pixel.Imagine that the image is composed of N-1 bit planes, ranging from plane 0 for least significant bit to plane N-1 for the most significant bit. In terms of N-bit planes, plane 0 contains all the lowest order bits in the bytes

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comprising the pixels in the image and plane N-1 contains all the high-order bits. In other words Plane zero is the Least Significant Bit (LSB) and Plane N-1 is the Most Significant Bit (MSB). Fig. 3 illustrates N Bit-plane decomposition of an image.

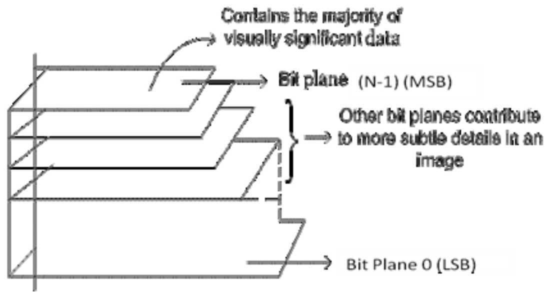

Fig.4: Bit planes Representation

For the importance of data rate, it is not needed to take into consideration all the slice contributions some planes can be ignored until the changes in gray level have an acceptable impact on the image. This approach will increase the data rate up to (N-1) times, by only transmitting most important significant bitplanes. Thus proposed bit slicing can be an efficient way of compression technique. To obtain more accurate 2D images, other bits can also be transmitted. Maximum resolution is obtained if all the bit slices from most significant to least significant are decoded at the receiver side without sacrificing resolution. Note that the most significant bit plane contains visually significant data. The other bit planes contribute to more subtle details in the image Bit plane

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IV.TURBO CODES

Turbo codes are capable of achieving a bit error rate of 10^{-5} at a channel signal-to-noise ratio (SNR) 0.7 dB, an improvement of almost 2 dB compared to the best previously known codes. The Turbo encoder employs two identical systematic recursive convolutional encoders (RSC) connected in parallel with an interleaver preceding the second recursive convolutional encoder. As shown in Fig.5 both RSC encoders encode the information bits of the bit slices.

The first encoder operates on the input bits in their original order, while the second one operates on the input bits as permuted by the interleaver.

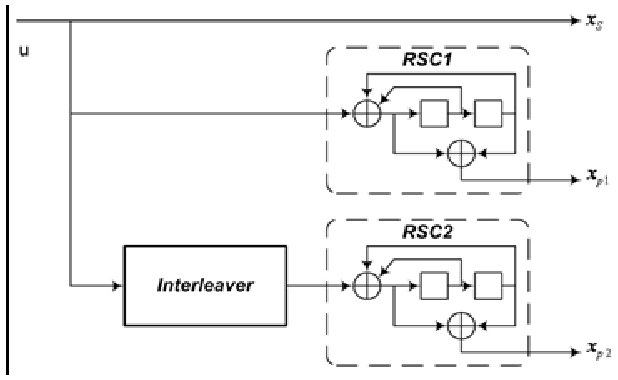

Fig.5: Turbo Encoder

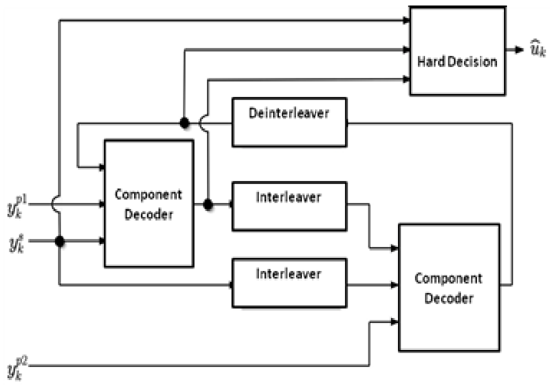

Fig.6: Turbo Decoder

The decoding algorithm involves the joint Estimation of two Markov processes (MAP) one for each constituent code.

The goal of the MAP algorithm is to find the a posteriori probability of each state transition, message bit, or code symbol produced by the underlying Markov process. Because the two Markov processes are defined by the same set of data, the estimated data can be refined by sharing information between the two decoders in an iterative fashion. The output of one decoder can be used as a priori information by the other decoder as shown in Fig.6. The iteration process is done until the outputs of the individual decoders are in the form of hard bit decisions. In this case, there is not any advantage to share information anymore.

Consider a half-rate RSC encoder with M memory size. If the d_k is an input at time k, the output X_k is equal,

$$X_k = d_k \qquad (1)$$

Remainder $r(D)$ can be found using feedback polynomial $g^{(0)}(D)$ and feed forward polynomial $g^{(1)}(D)$. The feedback variable is,

$$r_i = d_k + \sum_{j=1}^{K} r_{k-j}\, g_j^{(0)} \qquad (2)$$

and RSC encoder output Y_k which is as called parity data is given as

$$Y_k = \sum_{j=0}^{K} r_{k-j}\, g_j^{(1)} \qquad (3)$$

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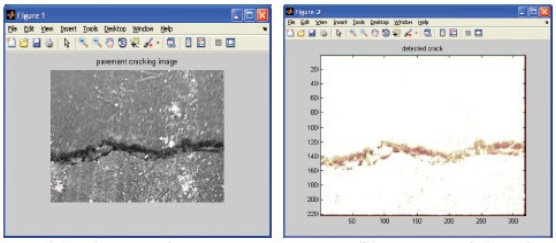
RSC encoder with memory M=2 and rate R=1/2 which feedback polynomial $g^{(0)} = 7$, feed forward polynomial $g^{(1)} = 5$ and it has a generator matrix

$$G(D)=[1,1+(1+D^2)/(1+D+D^2)] \quad (4)$$

where D is memory unit.

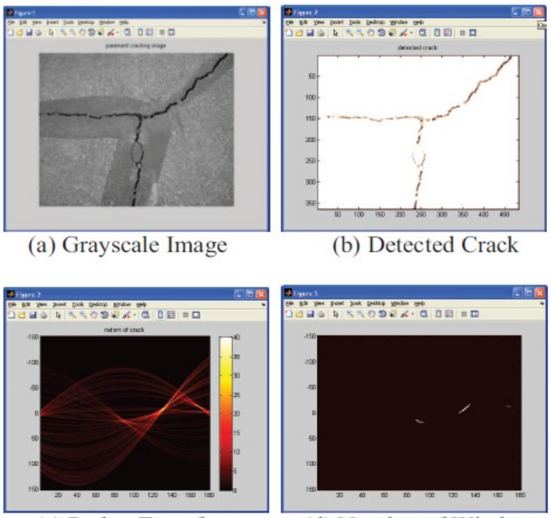
V.EXPERIMENTAL RESULTS

The images used in this paper were downloaded from the web in true color. A crack is composed of sets of pixels that are darker than the pixels in its surrounding areas. To better test the algorithm, various pavement images containing, longitudinal, transversal, diagonal, block, and alligator cracks as well as other irregularly shaped cracks are considered in the simulation. Figures 7,8, & 9 (a, b, c, d) represent an original pavement image, crack detected image, the Radon transform image, and the number of peaks windows for transversal, composite, and alligator type cracks, respectively.



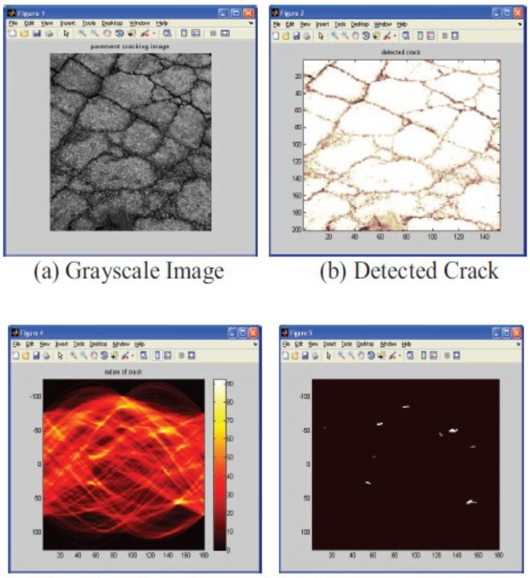
(a) Grayscale Image (b) Detected Crack (c) Radon Transform (d) Number of Windows

Fig.7 (a, b, c, d)



(a) Grayscale Image (b) Detected Crack (c) Radon Transform (d) Number of Windows

Fig.8 (a, b, c, d)



(a) Grayscale Image (b) Detected Crack (c) Radon Transform (d) Number of Windows

Fig.9 (a, b, c, d)

Table1.Classificatin of the image

Input Image	No. of Windows	θ	X	Max	Type
Figure 7	1	90	10	48	Traversal
Figure 8	3	90°, 130°, 180°	5, 0, -5	40	Composite
Figure 9	9	all	all	92	Alligator

The turbo processed images are capable of being robust towards noise. The two RSC encoders will efficiently perform the process of parallel concatenated encoding. The simulation results of the system combining the bit plane slicing with Turbo codes yield a very good and sensitive processing of images. The compression ratio is very high. Even with a use of lossy compression technique of bit plane slicing the visual effect of the reconstructed image resembles the original image. Turbo codes enable the image to become more robust to get the effected by the noise.The simulation results prove that the image reconstructed is having a very effective level of PSNR and hence it can be stated that this Process best suits for the techniques of video transmission. Particularly in the case of 3G technology video calling process, this technique provides a better performance in processing the image instantaneously and transmit with an effective PSNR.

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Fig10 Images Processed using bit plane slicing and Turbo codes

VI.CONCLUSION

In this paper, an algorithm that can be used for pavement image analysis is presented. This algorithm uses wavelet transform and pseudo coloring to detect the cracks and applies a Radon transform on the binary image to classify and evaluate the cracks. It has been shown that the Radon transform can be used to determine the possible type, location, area, length, and the width of the pavement distresses even from noisy images.

And, the proposed algorithm presented in this paper guarantees not only the processing effect but the processing speed, which satisfy the requirements for the pavement detection in the high-grade highway. And also in this paper an effective method of image transmission is investigated. The system combining the bit plane slicing technology and turbo codes results an efficient image transmission. This mode of transmission of images is robust towards the noise. Experimental results show that the visual effect is better and the encoding speed is 10 times faster than that of the Conventional Methods.

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