AUTOMATICALLY TIRE MARKS IDENTIFICATION AT ACCIDENT SCENE

Ying-wei WANG
Associate professor
Department of Shipping & Transportation Management
National Penghu Institute of
Marine & Management Technology
300,Liu-ho Rd., Ma-kung, Penghu,
TAIWAN
Fax: +886-6-9265760
E-mail: ywwang@npit.edu.tw

Abstract: This study proposes a structural approach to extract tire-mark texture features and characterize them with three features: (1) the numbers of the light peak, (2) the duration of the light peak, and (3) the variance of light-peak positions. These features could be used as the input data to train a back-propagation network. After training and validating the model, weights of links on the network are determined and recognizer is constructed. The identification rate for a single image-area on tire marks validated from case studies is 75%.

1.INTRODUCTION

Tire marks on roadway surface at accident scene are important data in accident investigation. They can be used to identify driver's behavior before the collision, vehicles' headings and velocities, collision position and post collision trajectories etc.
In Taiwan, marks on roadway surface at accident scene are collected by the policemen/investigators via using a simple camera. Data can be recognized by experienced experts in accident liability. However, this task is time consuming, high-cost, and easily to make misidentification. Therefore, if an automatically identification of tire marks is adopted, it could save time, cut cost and increase the correctness of identification on tire-mark recognition.

The pattern of tiremark recognized by human eyes is just like a light/dark mark on road surface. However, if we closely look at it, detail features such as parallel striation marks within tiremarks is existed. Each type of tiremarks has a distinctive feature. Therefore, the characteristics of these features can be used to distinguish the type of tiremark in digitized tire-mark recognition. Nevertheless, the formation of tiremarks on photo is influenced by many factors, such as tire surface condition, pavement and weather condition, camera's orientation and position, the quality and clarity of photo, etc. and would produce incomplete feature of tiremarks. These factors make the extraction of the characteristics of tire-mark feature a difficult task while using digitized image. Anyhow, the artificial neural network which learns for the noisy data (incomplete feature) was employed in a previous study using the raw data extracted from sample area in tiremark image as the input units to construct a recognizer for identifying the pattern of the tiremark. The identification rate of that model is acceptable, but still needs further improvement in characteristic extraction (Wang 1997).

In this paper, author used a structural method to extract the characteristics of tiremark to solve the problem of incomplete feature. These characteristics can be represented as the input units of artificial neural network to train output units to learn for classifying the patterns of tiremarks. After training and validating the model, weights on each links can be determined and a tiremark identification model is constructed.

This research describes first the causes resulting in tire-mark and factors influencing its formation. Secondly, a structural method for extracting the characteristics of tiremark is constructed and its operational procedure is explained. The constructing process of a recognizer for identifying the patterns of tiremark is then being presented. Finally, we address conclusions and suggestions of this research.

2. TIREMARK FORMATION AND INFLUENCING FACTORS

While a driver abruptly confront the hazard in driving course, he/she may undertake an action to evade or escape from the hazard. After undertaken full braking or steering action, tires will rub on the road and the heat will be produced between them. This friction heat will result in softening and melting the material (asphalt or tar) on bituminous concrete road and forming tiremarks, such as skidmark and yawmark, as shown in Figure1. However, on port-land concrete road where the material does not be soften by heat the mark may be composed of rubber that is rubbed or ground off the tire which being tacky from heat and sticks to the road surface. Therefore, a tire-mark formed on bituminous concrete road is more dark and durable than that on port-land concrete road. In general, tiremarks are made by three different ways: (1) tire sliding but wheel not rotating (skidmark), (2) tire slipping or scrubbing but wheel rotating (yaw scuffmark), and (3) tire not slipping but wheel rotating (prints). Each of them leaves a distinctive mark.

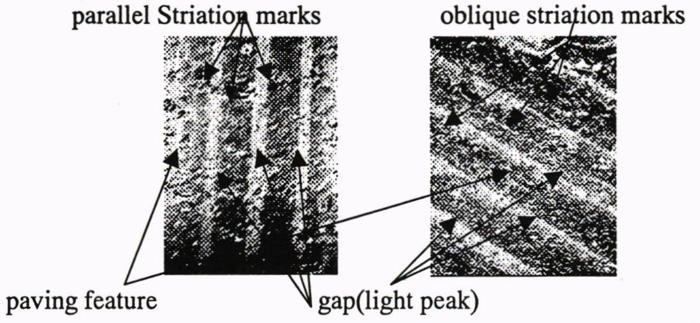

Figure 1 Typical Skidmark (left) and Yawmark (right)

Tire prints are usually produced by tires rolling on ground water, dropped oil or people's blood on the road. There is no specific relationship between tire prints and driver behavior. Nevertheless, skidmark and scuffmaik implicate different driver behaviors in vehicle operation. Skidmarks produced by tire sliding represent a driver paying attention to the traffic condition, discovering the hazard, and having a reaction time to brake to escape the hazard. On the other hand, yaw scuffmarks produced by tire slipping or scrubbing while wheel rotating represent a driver suddenly discovering a hazard but having not enough reaction time to tactical operation and conducting a quick turn to escape from the hazard. This difference is naturally important in understanding how an accident happen but, unfortunately, many accident investigators make no distinction between yaw scuffs and braking skids (Baker 1986). The purpose of this research is to develop a recognizer that can automatically identify skidmark and yawmark.

2.1 Influencing Factors

Tiremarks are usually recorded by photograph taken by policemen/investigators using a simple camera. The formation of tiremark on a photo is influenced by factors, such as pavement and weather conditions, tire condition, camera's orientation and position, the quality and clarity of the photo, etc. The following introduces major factors influencing the formation of tiremark on a photo.

(1) Pavement condition

Pavement condition is mainly influenced by road material and traffic. Material composed of asphalt, sand, gravel etc. and road traffic are the major factors resulting in specific features or coarseness of the pavement on roadway. There is a distinctive pavement condition in each road section and even in the same section pavement conditions are not the same via microscopic observation. This research discovers that pavement is the most important factor in influencing the feature of tiremark and is the key problem of background feature on tiremark image. For example, the feature of pavement on road section is the background of the feature of a tiremark on a photo, as shown in Figure 1. This problem also makes the extraction of tiremark's characteristics being very complex and difficult.

(2) Weather condition

Weather condition, such as brightness, wind and rain are factors influencing tiremark features and brightness is the most important factor. The feature of tiremark are changing mainly dependent on the brightness at the moment of photographing. Except for brightness, the wind and rain could erode marks and make them unclear or disappeared after a few months.

(3) Tire surface condiction

There are many kinds of vehicle tires and their surfaces (features) are completely distinctive. When sliding on the road, each tire with specific feature and pressure could produce a different type of tiremark. Furthermore, tires with deeper features can also produce darker tiremark; for example, a few dark parallel striation marks in the skidmark as shown in Figure 1. When tire is overdeflected, the edge of tread carries more weight than the middle; consequently, that is the place where most heat is developed when sliding. The edge of tire leaves stronger marks than the middle does and results in a special type of tiremark feature.

(4) Camera's position and orientation

The image of tiremarks is not clear from long distance photography. Nevertheless, the image of tiremarks is clear from short distance photography but the background feature of pavement will appear on the photo. These problems may be solved by photographing at a proper distance. However, the approach still needs to be developed. This research employs short distance photography with about 150-cm perpendicular center to the mark on road for the clarity of the photo and the convenience of taking photos by the investigators. Because camera's orientation can directly deform the objects on a photo, a suitable photographing orientation must be taken.

Some other factors, such as the quality and clarity of the photo, dirts on the road, small holes on paving, traffic marks, road environment, etc., may have minor effects on the tiremark's feature. These major and minor factors will together result in the problem of incomplete feature of tiremark texture on a photo and increase the difficulty and complexity of pattern identification.

3. EXTRACTION OF TEXTURE FEATURE

Methods for extracting the characteristics of tiremark feature can be classified into two categories: statistical methods and structural ones. Structural method uses the character of pattern unit captured in the space/structure to identify the type of the feature. The statistical method characterizes textural feature by a set of statistics extracted from a large sample of local property which represents inter-pixel relationship. In general, statistical methods are useful for very fine textures which do not contain any obvious "texture elements," nor regular spatial arrangement (Conners 1980, Haralick 1973, Matsuyama 1995).

Because pavement condition has a great influence on tiremark feature, the background feature of tiremark will be produced by microscopic observation. If we employ statistical approach to extract the textural properties, the extracted characteristics may be correspondent to the properties of pavement feature, not the tiremark feature on road surface. Therefore, a structural method for extracting the characteristics of tiremark's feature is employed to solve the problem of background texture in tiremank analysis. This method uses the properties of spatial distribution of normalized gray-level values in each sample area which corresponds to the feature element repetitive in space, as shown in Figure 2. Three characteristics of tiremark feature are defined as follows.

(1) The numbers of the light peak

The light peak shown in Figure 2 represents the two or more consecutive sampling points in which the corresponding normalized values are greater than zero. The light peak is the gap between parallel striation marks on tiremarks. On the other hand, the parallel striation mark is corresponding to the normalized value less than zero. In general, skidmark has three or four light peaks in a sample area and yawmark has only one or two light peaks in it.

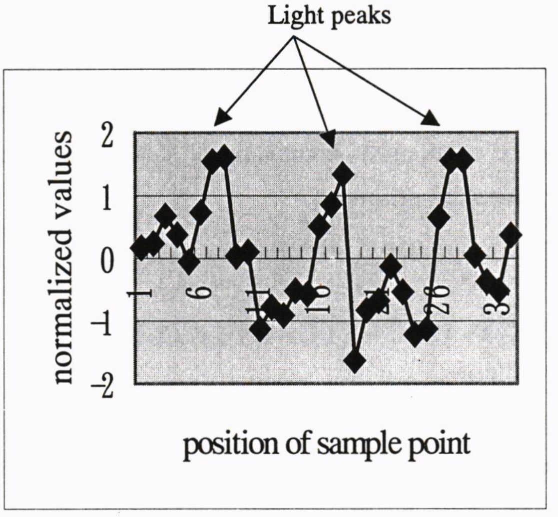

Figure 2 the distribution of the normalized values of the sample points

(2) The duration of the light peak

The duration of a light peak is the number of normalized values in a light peak. A longer duration of the light peak happened in sample area can be classified as yawmark and the short the skidmark.

(3) The variance of light peak positions

Variance of the positions of light-peaks can measure the deviation between the actual positions and supposed positions of light peaks along with the horizontal direction. The supposed position is determined by the regularity of feature element (light peak) produced on skidmark. The variance of skidmark is approaching to a fixed number while the variance of yawmark is very big.

The operational steps of structural method are described as follows.

(1) Digitizing the marks on a photo or directly using the digitized image of the marks from digital camera and segmenting the sections of those marks in the image.
(2) Partitioning each tiremark section into a lot of small areas, which shall sample 20 or 30 or 40 or 50 points along with the horizontal direction and each point being composed of a neighbor of 3*3 or 5*5 or 7*7 or 9*9 or 11*11 pixels.
(3) Normalizing the gray-level value of each pixel in a sample area and obtaining the normalized gray-level value of each sample point averaged by the pixels of each neighbor.
(4) Extracting the characteristics of each sample area.

(5) Obtaining the characteristics of each mark feature in each sample area and using them as input units for constructing a recognizer in tiremark identification.

4. A BACK-PROPAGATION NETWORK

Because tiremark feature is influenced by many factors, incomplete textural feature is happened even though it partially preserves the properties of the repetitiousness of the feature element in Geometry. To solve this problem, we employed an artificial neural network to construct a recognizer, because it could learn from noisy data (pandya 1995). The back-propagation network has three fully connected layers, namely, the input layer, the hidden layer and the output layer, as shown in Figure 3. The operation of back-propagation training algorithm for this network is briefly described below.

Input:

Normalized contour sequence of class *r*

$u_{i,r}$ i=1,2,….,N, r=1,2,…..,M

Desired net output:

$$dr=\begin{cases}1 \text{ for class } = r,\\ 0 \text{ for class } \neq r\end{cases} \qquad r = 1,2,\ldots,M$$

Actual node outputs (forward propagation):

Hidden layer:

$$u_j^1 = f\left(\sum_{i=1}^{N} w_{i,j}u_{i,r}\right), \qquad 1 \le j \le H.$$

Output layer:

$$y_m = f\left(\sum_{j=1}^{N} w_{j,m}^1 u_j^1\right), \qquad 1 \le m \le M.$$

Here, f(α) = 1/(1+ e^{-}), and $w_{i,j}$, $w^1_{j,m}$, are the weight connection matrices between the input and the hidden layer and hidden layer and the output layer, respectively.

Weight adaptation (back-propagation):

$$w^1_{j,m}(t+1) = w^1_{j,m}(t) + \eta\delta_m u^1_j$$

$$\textit{with} \qquad \delta_m = y_m(1-y_m)(d_m - y_m)$$

η is a learning coefficient and δ_m is the error term for node m in the output layer.

Similarly,

$$w_{i,j}(t+1) = w_{i,j}(t) + \eta\delta_j u_{i,r},$$

$$with \qquad \delta_j = u_j(1-u_j^1)(\sum_{m=1}^{m}\delta_m w_{j,m}^1)$$

δ_j is the error term for node j in the hidden layer.

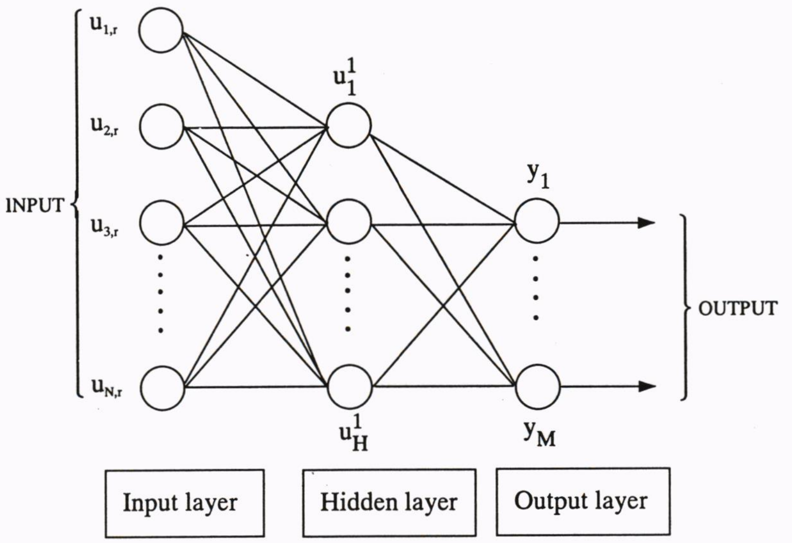

Figure 3 a Neural Network with three layers

Because the purpose of this research is to identify the two types of marks by using the three textural characteristics, the model can be concentrated. The practical model has three fully connected layers, which consist of the input layer with three units (N=3), the hidden layer with three units (H=3) and the output layer with two units (M=2). Therefore, the three textural characteristics defined above are used as the input units and the two type of marks, skidmark and yawmark, are represented as the output units.

The training data obtained by structural method from the practical marks on photo of road surface include 3500 records (2500 records for training and 1000 records for validating). This back-propagation network is trained by Gradient Steepest Decent method to minimize the error function, a mean square error function. The important parameters introduced in training process include learning rate, a momentum term. Learning rate for hidden layer is 0.9 and output layer 0.5. The value of momentum term is 0.4. After training and validating the model, weights on each link are determined, as shown in Table 1, and a recognizer by back-propagation network is constructed. The identification rate for a single-image area (a sample area) on tiremarks validated from case studies is 75%.

Table 1 weights on each unit

ITEM	UNIT 1	UNIT 2	UNIT3
HIDDEN* LAYER	-1.365693	4.445507	-1.418522
OUTPUT* LAYER	-0.845876	0.855289	-

* Each link from the input unit to the hidden unit or from the hidden unit to the output unit

5. CONCLUSIONS AND SUGGESTIONS

This study collected the data of marks on photo of road surface at accident scene. Based on the characteristics of tiremark textural feature extracted by structural method, a recognizer by back-propagation network is constructed. We can automatically identify two types of marks, skidmark, and yawmark by the recognizer. In this study, we obtain the following conclusions and suggestions.

(1) Conclusions

-Pavement texture, brightness, tire texture and pressure and camera's position and orientation are influencing factors but pavement texture is the most important one.

-This study proposes a structural method to extract the characteristics of textural feature of tiremark. The characteristics include the number of the light peak, the duration of the light peak, and the variance of light-peak positions. They are used as input units to train a back-propagation network.

-A recognizer of back-propagation network is constructed to solve the problem of incomplete textural structural feature, because it could learn from noisy data. The model can partially solve the problem of incomplete textural feature.

-Identification rate validated from case studies is 75% for a single-image area (a sample area) on tiremarks. This model can be applied by policemen/investigators to identify the types of tiremarks in accident investigation.

(2) Suggestions

-The characteristics representing the tiremark texture may be increased or improved by increasing the identification rate of the model constructed above.

-A suitable photographing distance can prevent the problem of unclear photo and background texture of tiremark on a photo and might directly improve the identification rate of this model.

-The structural method for extracting textural characteristics must be improved to preserve the rotation invariant property for the purpose of automatically identification.

ACKNOWLEDGEMENT

The work described in this paper forms part of the research project- The study of tire marks identification at accident scene using artificial neural network method, which was supported by the grant from the National Science Council of The Republic of China under grant number NSC 87-2211-E-346-001.

REFERENCES

Pandya, A.B. and R. B. Macy (1995)**Pattern Recognition with Nueral Networks in C++**, A CRC Book Published in Cooperation with IEEE Press.

Baker, J. S. and L. B. Fricke (1986), **The Traffic Accident Investigation Manual**, Northwestern University Traffic Institute, Evanston, Illinois 60204.

Conners, R. W. and C.A. Harlow (1980) A Theoretical Comparison of Texture Algorithms, **IEEE Transactions on Pattern Analysis and Machine Intelligence 2**, 204-222.

Haralick, R.M., K. Shanmugan and I. Dinstein (1973) Textural Features for Image Classification, **IEEE Trans. on Systems, Man, and Cybernetics 3**.

Dougherty, Mark (1995) A review of neural networks applied to transport, **Transportation Research.-C 3**, 4.

Matsuyama, T., K. Saburi and M. Nagao (1982) A Structural Analyzer for Regualarly Arranged Textures, **Computer Vision, Graphics, and Image Processing 18**, 259-278.

Wang, Y. W. and K. L. Ting (1997) Tiremark Identification Using Artificial Neural Network Method, **Proceeding of 30th International Symposium on Automotive Technology & Automation**, Florence, Italy, 295-300.