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Road Disease Real Time Detection Model on Multi-Lever Fuzzy Filter

Abstract. *A Multi-lever filter fuzzy detection model on road disease is taken forward combining with advantages of noisy decreasing algorithms and characteristics of noise and disease in road image. The experimental results indicate that the proposed model is more advanced in decreasing noisy and extracting disease. The application of the road disease edge detection was realized in embedded Linux system. The evaluation report will be output in real time and sent to the central database from the embedded mobile terminal, including the corresponding position information in the cooperative GIS.*

Streszczenie. *Technika road desease jest stosowana w przetwarzaniu obrazu do usuwania szumu z zamazanych obrazów i odzyskiwania obrazu krawędzi drogi. W artykule przedstawiono filtr wykorzystujący logikę rozmytą. (**Wykrywanie w czasie rzeczywistym zakłóceń obrazu drogi z wykorzystaniem filtru bazującego na logice rozmytej**)*

Keywords: Image processing, Road disease detection, Embedded Linux system, Multi-lever filter.
Słowa kluczowe: przetwarzanie obrazu, technika road desease.

1. Introduction

Road disease detection techniques are primarily used with photographic and video technology. It can capture roads damaged condition dynamically and instantly, and then use image processing technology to process the road image and quantitative analysis damaged road surface conditions, such as diseases. In order to find the much precise way of road crack detection, it is need to compare several algorithms, such as Sobel operator, Prewitt operator, Robert operator, Laplace operator, LOG operator, Canny operator and so on. Sobel and Prewitt both do difference and filtering to detect the edge of images, but with different weights in smooth part and detecting the much thick edge in increasing epsilon neighborhood of window. Robert directly computes the difference of image without smooth, being sensitive to noise. Laplace is a second differential algorithm, and the influence of noise to image is enhanced [7]. Firstly, LOG operator uses Gaussian function to smooth the original image, then adopts non-directional Laplace operator to compute to get zero cross point as the edge, even though being simple and easy to achieve, this algorithm detects false edge in little change of grayscale and is sensitive to noise and not good at anti-jamming, without clear enough edges. On Contrast, the Canny operator is an optimization algorithm for high Signal-to-Noise and precision of detection [8]. Because it firstly establishes theoretical principle of optimization edge detection operator, proposals the three standards of edge detection which are defined most strict so far. Ghosh Ankush et al proposed and employed a lower bit plane modulation for hiding a binary image like information within a gray scale image, which is shown that the low cost data embedding algorithm can conceal watermark into original cover image coming from a sensor much faster than software implementation [6]. Bondani Mari et al theoretically demonstrate that detectors endowed with internal gain and operated in regimes, and ensure linear input/output responses, can allow a self-consistent characterization of the statistics of the number of detected photons [7]. It is necessary to link the environmental factors and the needs of application to do road edge detection. However, traditional image processing algorithms are not very effective used in road diseases detection, image processing technology in dealing with road diseases image had not been made fully reliable analysis. Improved algorithm for road diseases image processing must be resolved.

With further increasing in highway mileage, the workload of road disease detection resulting from increased, which requires detection equipment road towards high-performance, cost-effective, real-time processing direction. But in the past, the road disease detection system usually use embedded terminal to resolve image sampling, analysis, processing, storage, and the resulting output, the terminal's handling capacity is often insufficient to support the real-time systems; another problem is hard to associate with disease information and the location of the road.

In order to solve these problems, this paper discusses some the problems in Canny algorithm, then presented several improve methods, different methods are compared. In order to find the most suitable method of improving the detection of road diseases, this paper also proposed a novel multilevel noisy decreasing model based on the detection of road disease.

The embedded road disease detection system uses 32-bit embedded ARM development board as the terminals, combined with the open-source embedded Linux system Qt/E to complete the development of graphical interfaces. It can process images in real time, receive disease information, and send disease and location information back to the cooperative service platform.

2. Image Detection System Structure Model

The road disease detection model concludes an image input module, an image detection module and a result output module. The detail can be seen in Fig.1.

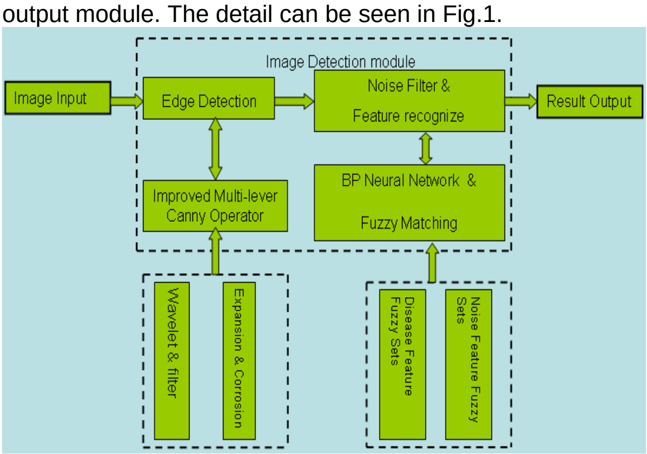

Fig. 1 System architecture

The images will be gotten from video stream in the image input module. There are processes of image edge detection and noise filter & feature recognition. The recognized report about road disease will be produced in the result output module.

In the process of image edge detection, the wavelet filter, expansion & corrosion of morphology are utilized to improve the Canny operator in order to restrain noises and improve the quality of image edge detection. In the process of noise filter & feature recognition, two fuzzy sample sets, namely, noise feature fuzzy sets and disease feature fuzzy sets are used to match disease and noise by a BP neural network & fuzzy matching algorithm.

3. Multi-lever Filter on Noise

Binary edge map can be got after the classical Canny algorithm, but it can't be used to analyzing disease directly, because there are much noise especially on the road. Consider with road features, we mainly talk about zebra crossing, manhole covers and shadows.

3.1 Removing the Zebra Crossing

Zebra crossing in the road is usually white or yellow, while diseases are always black or gray. Therefore, here we set the point whose color is nearly white or yellow as background points before graying. In this way, influence of zebra crossing is avoided while time complexity has not been increased.

3.2 Removing the Manhole Covers

The shapes of manhole covers are always rounding, but diseases are rarely like that. Then we filter the edge-detected image using a filter which is formed by two nested different-sized squares. If there are lots of key point in the bigger square while a few in the smaller one, it proves that this piece has a circular shape and we should throw it out. This algorithm has good performance in the experiment though it's not the optimal one. Further research is now in progress. The steps of removing the manhole cover are in the following as Fig.2.

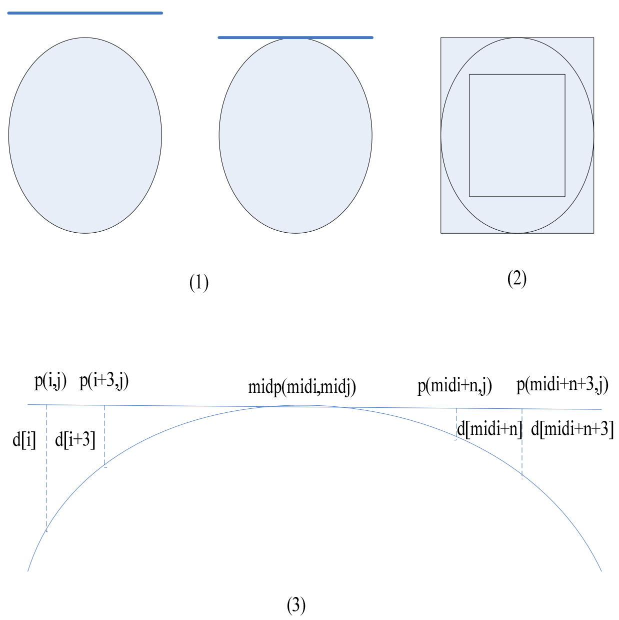

Fig. 2 Removing the manhole covers

Procedure of removing the manhole covers is as follow.

Step 1: From each pixel of the image, draw a fixed-length line. If the number of key points in the line is less than a define threshold and also the points near the mid are key points, then jump to the next step. Otherwise, move our focus to the next line. If all the pixels are traversed, jump to step (5).

Step 2: Draw a square using the line as the upper side. In the same time, draw another smaller square concentric with that square. Count the key points in the smaller square (pis) and key points between the two concentric squares (pbs). If pbs is over ten times more than pis, jump to the next step. Otherwise, go back to (1) and get the next line.

Step 3: For each points p(i, j) in the line, find the first key point just below it and count the distance between them d[i]. Define the mid of the line is point midp(midi, midj). Check d[i], if in the left of midp, each d[i] is larger than d[i+3] and also each d[i] is smaller than d[i+3] in the right of midp, jump to the next step. Otherwise, go back to (1) and get the next line.

Step 4: Set all pixels in the larger square to background pixel.

Step 5: Erase all the lines and squares we drawn in step (1) and (2)

3.3 Removing the Shadows

Shadows and diseases on the road are similar in color. Here we mainly talk about car camera shadows, wire and wire pole shadows, tree shadows and some other object shadows. There are shadows in the four corners and bottom half of images shot by our camera, so we should set color of these area as background color to avoid error. In the same time, wire and wire pole has regular shape, we can throw out them using predefined model.

3.4 Classification of Diseases and Calculating of Eigen Values

We can get the road disease image after multi-level de-nosing, and the results of experiment showed that recognition ratio using this algorithm has reached 90%. Then we classify the diseases, using algorithm based on pattern matching, into transverse diseases, longitudinal diseases, block diseases and checking diseases according to domestic standard, and finally calculate eigen values such as length, width, area and so on.

3.5 Improved Canny Algorithm

The steps of improved Canny are in the following:

Setp 1: Input the image;

Setp 2: Gray the image and remove the zebra crossing;

Step 3: Smooth the image with a chosen Gauss filter, and define the image after Gauss filter as $I(x,y)$. Here, the Gauss filter we use is:

(1) $$G(x) = \frac{1}{2\pi\sigma}\exp\left(-\frac{x^2}{2\sigma^2}\right)$$

Step 4: Determine gradient magnitude and gradient direction at each pixel with formula (2) and (3).

(2) $$M(x,y) = \sqrt{g_x^2 + g_y^2}$$

(3) $$\theta(x,y) = \arctan(g_x / g_y)$$

Step 5: Non-maximum suppression. Traverse the image, if the gradient magnitude at a pixel is larger than that at its two neighbors in the gradient direct, mark the pixel as a possible edge. Otherwise, mark the pixel as a background. Define the set of possible edge pixels as W.

Step 6: Calculate gradient of each pixel in W, and then calculate the high threshold (TH) and the low threshold (TL) according to gradient histogram.

Step 7: Define a new set F. Traverse each pixel in W, if its gradient is larger than TH, put it into F and remove it from W.

Step 8: Traverse all pixels in W. If the gradient of a pixel is less than TL, then get the next pixel. Otherwise, if it has a neighbor in F, then move it to F and search its 8 neighbors according to Depth Finding Strategy.

Step 9: Removing the manhole covers and shadows.
Step 10: Output F. F is the edge pixel set.

4. BP Neural Network Matching Algorithm on Fuzzy Sets

There are Four methods are used to classify the objects, including matching on image gray, matching on features, matching on model and matching on transformed domain. The matching method on image gray setups the similarity between two images with the image gray. A search way is used to find the maximum or minimum transformed model parameter value on their similarity. This method has good precise and robustness because it does not extract the features but only uses the image gray. Because of its great computation and increasing matching errors in Information poor region, it can not be suit for recognition of the road diseases.

The matching method on features only matches and computes some features, for example range, histogram, frequency coefficient, points and lines, it keeps some invariant features as the edge point, the center of close region, line, surface and array for matching two images. Its advantage is to extract the significant features and compress the information content of image, the computation decreases, becomes faster and keeps good robustness. In one side, because only a few images gray is used, this method is sensitive to matching and recognizing of the features with low precise.

The matching method on model is wildly applied in computer vision. The matching computation is one point by one point in the whole matching region; it is also sensitive to the noises, which must be eliminated. In matching process, matching with rigid shape and deformable template can be utilized to improve the convergence of the concave edges and sensitivity of the noises. The matching method on transformed domain includes Fourier transformer, Gabor transformer and wave transformer; the matching method on frequency domain can bear the noises and keep the invariance of rotation and size. Its result is not related to illumination.

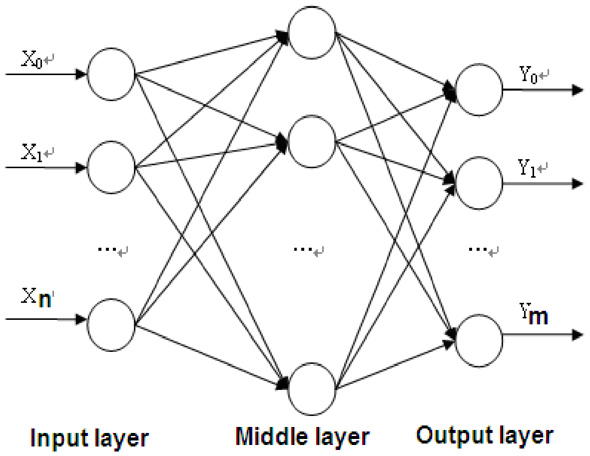

Fig. 3 BP neural network

In recognition algorithm, BP neural network is utilized for its good convergence. Firstly, a construction of BP neural network must be adaptive to recognize the disease. In the sample database, ten sample feature matrixes and their target matrixes are setup from ten type diseases. The feature matrixes are 22*1 dimension matrixes, and the target matrixes are 10*1 dimension matrixes. The number 22 is the vector number of the features, and the number 10 is the number of the types. The number of the neuron is 22 in input layer, the number of the neuron is 10 in output layer, and the number of the neuron is adaptive in middle-layer according to some experience. The experience formula is defined as follow.

$$n_1 = \sqrt{n + m} + a \qquad (4)$$

In the Eq. 4, n is the number of the input layer neuron, m is the number of the output layer neuron, a is a natural number in the area [1, 10], n1 is the number of the middle layer neuron. In this system, n1 is about 15. The details of BP neural network can be seen as Fig.3.

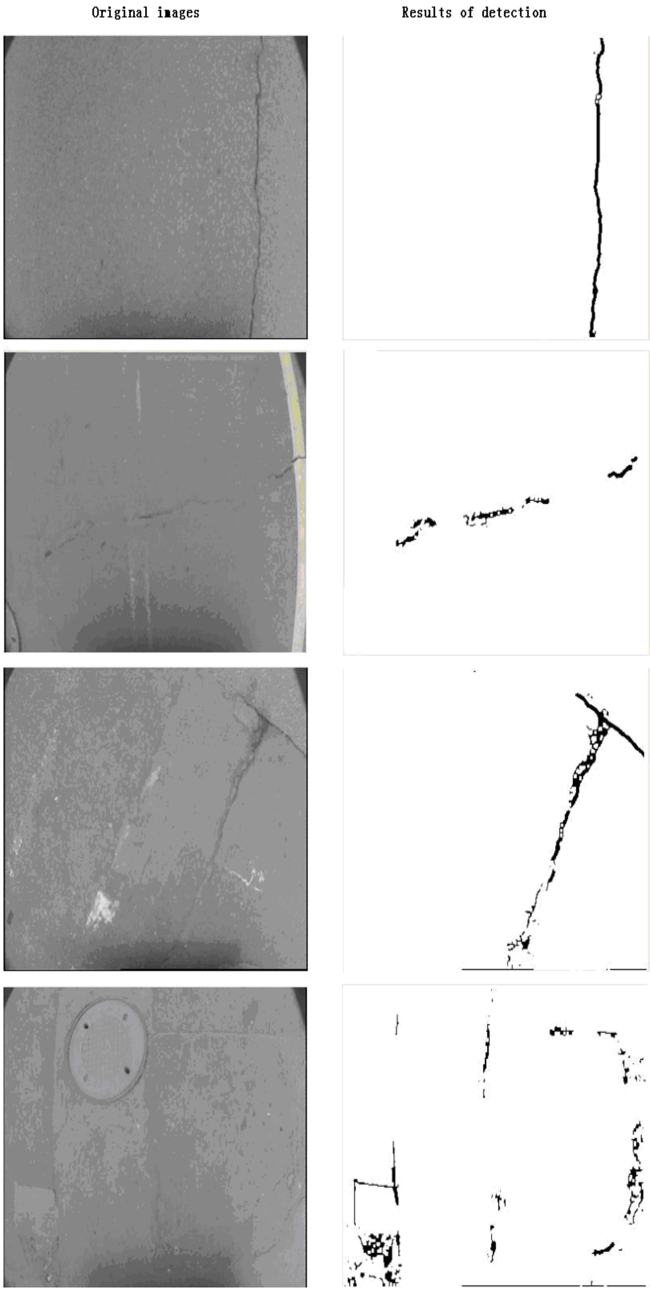

Fig. 4 Results of BP matching algorithm on fuzzy sets

In the second step, the neural network must be trained with the sample feature matrixes and their target matrixes. Value of the function Sigmoid is in the area (0, 1), the data in input and output must be normalized in the area (0, 1). Weight matrices of 22*15 and 15*10 are randomized in the area (-0.5, 0.5). In training, tolerance is set to 0.001 so that the difference between the sample feature matrixes and their target matrixes is the minimum. If the tolerance is less than 0.001, and the feedback number is 10, this training is successful and ended; otherwise, it must be restarted.

In the third step, the weight matrices are gotten. After the all samples are trained, and a satisfied result is gotten, the weight matrices will be setup, which is saved in a txt format file and reused. Lastly, the image targets are recognized. The weight matrices are use to recognized the input image targets, the result will output. According to the result, if there are some samples in the current image, then the types of the disease and noise will be judged and accounted; otherwise, they do not exist in the current image.

BP neural network & fuzzy matching algorithm recognizes and induces the recognized case to disease or noise with two fuzzy sample sets, namely, noise feature fuzzy sets and disease feature fuzzy sets. If the case is a type of disease, it will be reserved and analyzed; otherwise, it will be noises, and be filtered. The details of the matching algorithm can be seen Fig.4.

5. The Case of the Embedded Road Disease Detection System

Table 5.1 Recognition accuracy of disease detection system

Projects	zebra line	cover	accuracy
vertical cracks	yes	no	93%
	yes	yes	78%
	no	yes	79%
	no	no	93%
horizontal cracks	yes	no	89%
	yes	yes	79%
	no	yes	81%
	no	no	90%
block cracks	yes	no	78%
	yes	yes	68%
	no	yes	74%
	no	no	82%
net cracks	yes	no	77%
	yes	yes	69%
	no	yes	73%
	no	no	81%

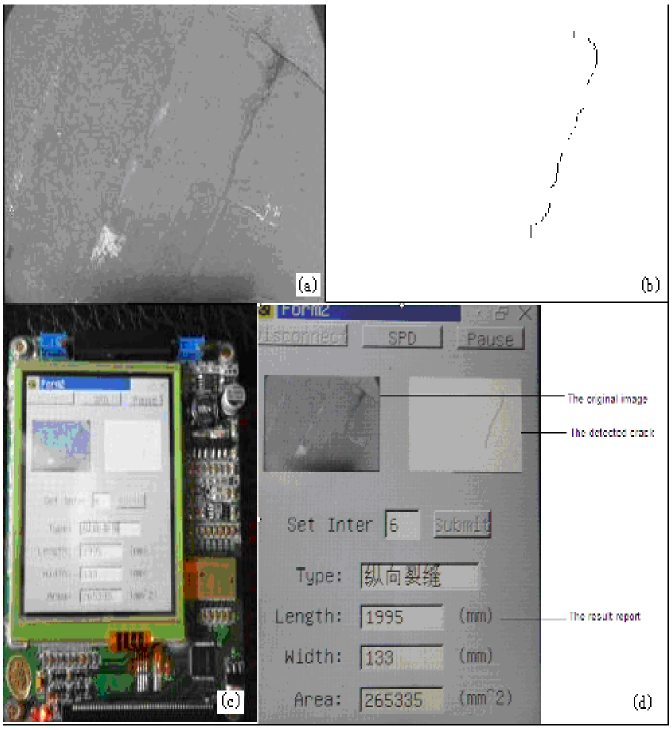

Fig. 5 (a) Original Image acquired by the terminal (b) The disease after image detecting (c) Embedded system terminal (d) Result of the disease detection by embedded software

In table 5.1, the model has good recognition performance for vertical cracks and horizontal cracks, whose accuracy is about 90%; but accuracy of net cracks and block cracks does not feel good. This model can filter the noise effect such as zebra line, lane line, cover, oil, shadow and sewage. The result indicates robustness of the model on the noises. The model algorithms are embedded a hardware terminal device.

The embedded road disease detection system terminal has good performance during the test. An instance is presented in the following. Fig.5(a) and Fig.4(b) show the effect simulated on PC platform, Fig.5(c) and Fig.5(d) show an instance of embedded terminal which is detecting on a road [11].

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