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# Research on Infrared Image Fusion Technology Based on Road Crack Detection

**Guangjun Li, Lin Nan*, Lu Zhang, Manman Feng, Yan Liu, Xu Meng**

China Merchants Chongqing Highway Engineering Testing Center Co., LTD., Chongqing 400060, China

****Corresponding author:*** Lin Nan, liguangjun1@cmhk.com



**Abstract:** This study aimed to propose road crack detection method based on infrared image fusion technology. By analyzing the characteristics of road crack images, this method uses a variety of infrared image fusion methods to process different types of images. The use of this method allows the detection of road cracks, which not only reduces the professional requirements for inspectors, but also improves the accuracy of road crack detection. Based on infrared image processing technology, on the basis of in-depth analysis of infrared image features, a road crack detection method is proposed, which can accurately identify the road crack location, direction, length, and other characteristic information. Experiments showed that this method has a good effect, and can meet the requirement of road crack detection.

**Keywords:** Road crack detection; Infrared image fusion technology; Detection quality

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## 1. Introduction

Roads play a vital role in people’s daily activities and are the basic public facilities of cities, but their construction and maintenance costs are very high, therefore the road structure and transportation should be carefully planned. There is a lot of investment in road infrastructure around the world. The US Land Transportation Act allocated around 30.5 billion US dollars in the fiscal year 2016-2021, for roads, automobile safety, public transportation, automobile transportation safety, dangerous goods safety, railways, research, technology development, and statistics. The infrastructure and jobs legislation, is the long-term investment in infrastructure and the country, will add $5.5 trillion in new federal funding for roads, bridges, buses, water conservancy facilities, and communications between 2022 and 2026 financial years. According to the statistics of highway infrastructure and traffic in China, the number of highway engineering and traffic has developed rapidly. Past ten years, China’s passenger throughput has decreased from 2.5 billion to 570 million, while national cargo throughput has increased from 2.5 billion tons to 3.7 billion. Cargo throughput has been maintained at a high level; Although the passenger flow has decreased, the effect of passenger traffic on road load is much smaller than that of freight, and the effect of the overall traffic on road load is very significant. From April 2018 to May 2019, there were 244 urban roads collapsed across the country. The stress on the pavement exceeds the load-bearing capacity of the pavement is an important factor causing collapsing of the pavement. Under the long-term load on the pavement, the pavement structure will be deformed, cracked, and even collapsed. With the extension of the service life of the road, long-term exposure to harsh environments, as well as the load and overload of vehicles and pedestrians, will cause long-term losses. Therefore, there is an increasing demand for road safety and sustainable development. It is also important for continues repairing and construction. Highway cracks are the most common ones that affect the bearing capacity of the pavement, accelerate the destruction of pavement to pieces, and reduce the service life of the road. Cracks are an important symbol used to measure the damage state of the road, and development direction directly affect the damage of the road. Infrared imaging technology has the advantages of mature technology, high sensitivity, non-contact method, and not required to touch the bridge itself to detect the bridge cracks. The road crack detection method based on infrared imaging technology can quickly and accurately detect road cracks. However, due to the characteristics of large noise and serious blur in infrared images, the detection results of road cracks are seriously affected.

## 2. Infrared image fusion technology based on road crack detection

At present, the routine inspection of road cracks is mainly performed manually, which is time-consuming, laborious, and dangerous. Many scholars are studying the service life of roads, but to accurately estimate the service life of road surfaces many factors have to be considered such as time, load, environment, etc. Therefore, non-destructive detection technology, as shock echo, ultrasonic, ground penetrating radar, infrared imaging, etc. should be used for detecting road cracks [1-5].

As a non-destructive technology with wide application value, infrared imaging technology is of great significance in the detection of cracks in concrete pavement. It plays a pivotal role in many modern remote sensing technologies such as drone navigation, pedestrian monitoring, space warning, and oil spill detection. However, due to shortcomings of infrared image itself, such as blurred edges, low background contrast, and local unevenness, it is difficult to ensure its accuracy and robustness. However, there are some imaging technologies that use infrared imaging technology to detect surface defects of objects. It is still difficult to perform accurate positioning and detection in thermal imaging. Therefore, it is essential to combine the advantages of infrared and visual images to identify better fusion and robust, and accurate infrared image segmentation technology.

### 2.1. Infrared image preprocessing

Due to the influence of environmental conditions and other factors, the collected road images often have different degrees of noise, which will directly affect the accuracy of the road crack detection algorithm, therefore infrared images should be preprocessed before use. Since the infrared image is greatly affected by the external environment and is easily disturbed, it needs to be denoised. In addition, due to the large amount of noise on the road crack surface, when the traditional image processing method is used for denoising, the extracted crack feature information becomes distorted. Below are the examples of denoising techniques.

(i) Median filter denoising is an image denoising algorithm based on statistical characteristics. This algorithm gathers pixels of different scales and different gray levels to form an average value containing all pixel information as the target image [6]. The median filtering algorithm has the advantages of fast operation speed and simple parameter setting. However, although the median filter can effectively suppress the influence of noise, it cannot eliminate all the noises. In addition, this method can affect the detailed information of the image to a certain extent when extracting road crack features [7].

(ii) Histogram equalization is an image denoising algorithm based on grayscale transformation, which achieves image enhancement through histogram transformation [8]. It does not require additional gray scale transformation operations [9], and can effectively process both noise and noise-free images [10].

(iii) Median filtering combined with histogram equalization. When the median filter is used to preprocess the image, it usually causes a certain degree of noise interference. In order to better extract the characteristic information of road cracks, a combination of median filtering and histogram equalization should be used for processing.

(iv) The infrared image will be disturbed by various noises during the acquisition process, including the environmental noise of the camera and the noise of the image itself. When detecting road cracks, these noises will seriously affect the crack detection results. In order to eliminate the interference of these noises on the detection of road cracks, the image processing paper uses wavelet transform and image pyramid technology for image preprocessing, and analyzes and compares them through experiments. Wavelet transform is a time-frequency analysis method with multi-resolution decomposition characteristics, and it is widely used in the field of signal processing. In infrared image preprocessing, wavelet transform can realize multi-resolution decomposition. Under different decomposition scales, image information with different resolutions can be obtained. In this paper, 4×4 resolution wavelet packet decomposition and pixel-level fusion method are used for multi-scale fusion of infrared images.

### 2.2. Image fusion algorithm design

The overall flow of the infrared image fusion algorithm is shown in **Figure 1**. Firstly, the pixel-level information is obtained through the pixel gray mean and variance of the infrared image, then, according to the pixel-level information, the correlation between adjacent pixels is calculated, and finally, the images are fused according to the correlation coefficient to obtain the final fusion results.

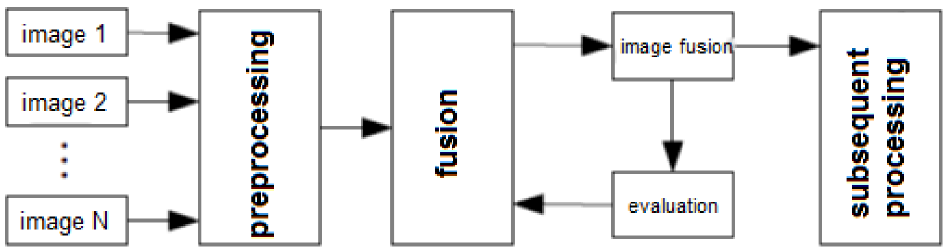


**Figure 1**. Overall process.

Below are the types of image fusion algorithms.

(i) Principal Component Analysis (PCA) is a linear algebra method for dimensionality reduction, which maps image data to a high-dimensional space through linear transformation, and then analyzes the original data in a new dimension. PCA transform image features into a high-dimensional space through projection for feature extraction.

(ii) Wavelet transform (WT) methods is an information processing technique based on multi-resolution analysis and multi-scale decomposition. WT has strong spatial resolution and good localization characteristics, and under different scales it can complete the extraction of different scale information in the image respectively and obtain the final result through comprehensive analysis and weighted summation.

(iii) Image fusion method based on regional features (IHB-AF) is an image fusion method based on regional features. This method uses regional features to describe the image and uses the geometric shape and gray information of the region to iteratively calculate the fusion coefficient in multi-scale space. Because IHB-AF organically combines pixel-level information and feature-level information, the fusion image not only preserve the gray level difference between the target and the background in the original image, but also reflect the difference between different feature points, and has strong anti-noise ability and anti-aliasing ability.

(iv) Based on the combination of maximum likelihood classification (MLC) and Laplacian pyramid decomposition method (LP). The MLC algorithm can perform maximum likelihood estimation on the source image, and the calculation process is simple, but it needs to store a large amount of data for calculation and processing, while LP algorithm is simple in calculation and can compress a large amount of data into a smaller space, but it is difficult to achieve real-time processing and quick analysis. This method uses the combination of MLC and LP algorithm to form a fusion algorithm, it not only effectively reduces the computational complexity, but also ensure the fusion effect.

## 3. Road crack detection algorithm

The detection of road cracks is a complex task, not only the type, shape, location and length of road cracks should be considered, but also the influence of the surrounding environment and other factors on the detection results have to be considered as well. Therefore, when performing road crack detection, it is necessary not only to select the appropriate fusion algorithm, but also to select the appropriate fusion method according to the actual situation. The road crack detection algorithm based on the deep learning can identify the target, but it requires a large number of training samples and high computational complexity. The road crack detection algorithm based on the fully connected neural network can effectively solve this problem.

Convolutional neural network (CNN) is a convolutional neural network model, which mainly composed of input, output, and hidden layer. In the network, the input layer is a series of image samples, while the output layer is image information (**Figure 2**). CNN consists of three parts; 1: input layer; 2: hidden layer; and 3: output layer. The input image samples are processed through image preprocessing, convolution operation, and fully connected network, and the output information includes two parts, which are road crack information and image features. Road crack information mainly includes crack position, length, and width. Image features include light direction and gradient information. After the input image sample is preprocessed, the preprocessed image is used as the input layer of the network, and the CNN network is used for road crack detection. Since the relationship between road cracks and the surrounding environment needs to be used to judge the direction and length of road cracks in actual detection, this paper uses a fully connected neural network as the network model. The neural network is a deep convolutional neural network model with supervised learning capabilities. When detecting road cracks, the convolution method is firstly used to extract the edge information of road cracks, and then the full connection method is used to complete the identification of road crack position, direction, length, and other characteristic information.

In this paper, a method based on CNN is used to detect road cracks. Firstly, the region of interest in the multi-resolution infrared image is extracted, and the multi-resolution infrared image is decomposed by using multi-scale wavelet packet transform to obtain the high-frequency coefficients of the high, medium, and low sub-bands; Secondly, the low-frequency coefficients are extracted for fracture area information, while K-means clustering method is used to cluster the high-frequency coefficients; and finally, the multi-scale fusion technology is used to process the low-frequency coefficients to obtain the final fusion image. Among them, the low-frequency coefficients are calculated from the low-frequency sub-band information after wavelet packet decomposition, and the high-frequency coefficients are calculated from the high-frequency sub-band information after wavelet packet decomposition. Since there are a large number of background noises and roads in the infrared image, median filtering and Otsu threshold segmentation methods are also used to process the fused image.

Therefore, this paper combines the fully connected neural network (CNN), which not only realize the extraction of image features, but also realize the recognition of crack features.

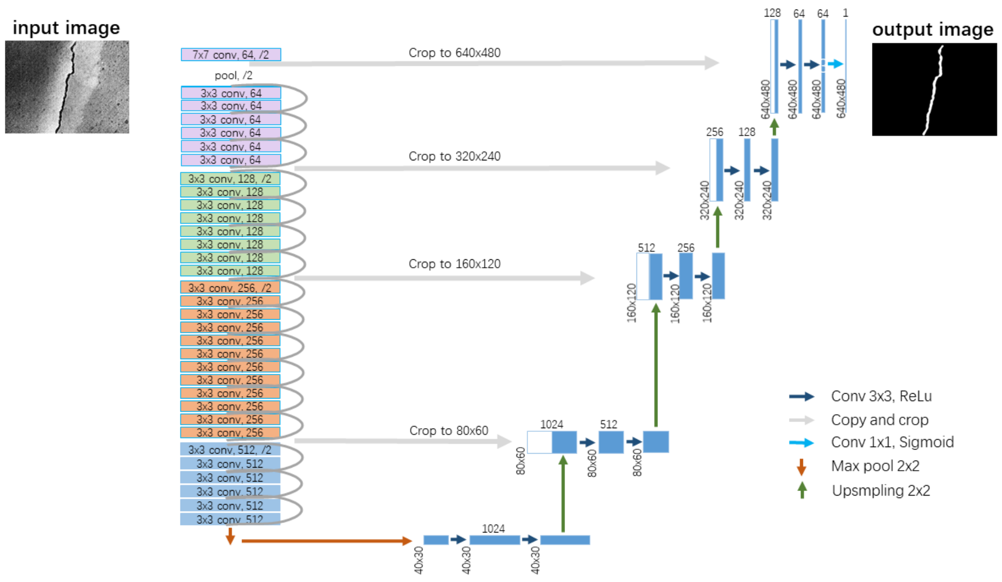


**Figure 2**. Model structure.

## 4. Conclusion

In the course of the experiment, considering that the threshold selection in image fusion has a great influence on the fusion effect, the infrared image fusion technology used in this paper has a better effect after fusing different types of road cracks, and can detect road cracks in low-light environments. Characteristic information such as the position, direction and length of the crack, and in a high-illumination environment, local feature information of road cracks can be detected.

## Disclosure statement

The authors declare no conflict of interest.

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