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Computer Vision Methodology for Structural Health Monitoring

Li-Hong Juang*, Wei-Jen Chen and Lixin Zheng

Science & Technology Innovation Center, Engineering College, HuaQiao University, Fujian, P.R. China

Abstract

Currently, the security of large civil engineering structures more and more people's attention, health monitoring study civil engineering at home and abroad is one of the hot topics of research. After a hundred years of research, the traditional structural health monitoring theories and methods continue to improve, and now there have been a lot to be able to use the results of the actual engineering and have been widely applied to large bridges and other structures, but there is a lot of its own defect. With the development of computer technology, people began to use computer vision to health monitoring, and gradually formed a monitoring method of mechanical vision. This paper introduces the significance and application health monitoring methods, and some of the traditional health monitoring methods are introduced. Then reviewed the development and the use of machine vision health status monitoring, and finally to crack measuring, for example, using wavelet recognition method for image recognition and analysis of fracture.

Keywords: Health Monitoring; Damage Identification; Machine Vision; Wavelet Analysis; Fracture Identification

***Corresponding Author:** Li-Hong Juang, Science & Technology Innovation Center, Engineering College, HuaQiao University, Fujian, P.R. China; E-mail: puuan.juang@msa.hinet.net

1. Introduction

Currently, the study of structural health monitoring method in the world are a hot topic. In 1996, control of the General Assembly on international structures scholars have proposed the establishment of three specialized working groups for structural health monitoring in Europe, Asia and the United States. Since 1997, every two years regularly convene an international agenda for structural health monitoring at Stanford University. In 2000, the American Society of Civil Engineers in the organization of the "structural health monitoring of standards," the research topic. Our country is in the mid-1990s under the auspices of "Climbing Plan" and the National Natural Science Foundation began to study the problem of structural health monitoring [1].

Overall, structural health monitoring in civil engineering is still a relatively new discipline, after a hundred years of research Despite many achievements, but many of its findings have not made use of the civil engineering go, confined to laboratory research stage [2]. Structural Health Monitoring began in the 1950s abroad, initially mainly used in aerospace and mechanical and other fields. Early health monitoring tools rely mainly on manual monitoring of experienced engineers and structural health status and trends judgment [3]. Research in the field of civil engineering is probably the early 1980s, researchers mainly use aspects of health monitoring research in bridge engineering and high-rise buildings. In the 20th century, 70-80 years, in order to monitor the safety of offshore oil platforms, people have done a study [4] use health monitoring system to monitor mining platform. Currently, structural health monitoring study abroad in civil engineering mainly in four aspects reservoir (dam), bridges, maritime measures, high-rise high-rise building [5]. In addition, in the protection of historical heritage buildings, public measures have also been using roads.

Structural health monitoring through a hundred years of research, now have a relatively complete theoretical system. In Study sensor technology, Sun and other changes in the electrical impedance presented by PZT monitoring structural damage, the current, thereby the piezoelectric transducer made of theory has been widely used. New sensors, in 1978, Hill et al found that the photosensitive phenomenon in Canada, and the use of legal standing create the world's first fiber grating. In 1989, the United States Meltz invented a germanium-doped fiber outer purple write technology, these studies so that the optical fiber manufacturing costs, it becomes possible to make extensive use of [6], in theory, the sensor arrangement is currently the most widely used by the Kammer [7] proposed effective independence method (EI).

Theoretical study abroad in damage recognition is also very rich, in the 1960s at the University of Michigan Professor Holland America proposed genetic algorithms, such as the use of genetic algorithms thereafter Koh local search, by measuring excitations and responses to structural parameters identification, discovery load Location great impact on the recognition results [8]. In addition to genetic algorithms, wavelet transform scholars have also done a lot of research, such as the Mexican Hat Wavelet Segawa such as the use of the system input acceleration and acceleration response analysis to identify the damage caused by the parameter structure, Hear wavelet analysis theory, etc. Health Monitoring Benchmark American Society of Civil Engineers (ASCE) proposed (health monitoring benchmark prob-lem) were studied, and the results of wavelet theory especially suitable for on-line monitoring of the conclusions [9], in 1992, the famous French Information Sciences IR ISA institution of Zhang et al. [10] proposed a wavelet neural network concepts and algorithms. With the development of computers, scholars began to try to use image processing techniques to study structural health monitoring. In 1983, American University of South Carolina's M, A, Sutton made a digital image correlation method [11], later scholars through research efforts, now photo grammetry has been commercialized abroad [12]. US logistics home Satty in the 1970s proposed AHP in safety assessment methods research system, professor Zadeh proposed fuzzy comprehensive evaluation method [9] in 1965.

In China, structural health monitoring is mainly used on a number of important large-span bridges, many researchers also research-based bridge monitoring. In the study of Tsinghua University sensor arrangement problem right Qin et al Tsing Ma Bridge in Hong Kong optimal sensor placement problem is studied, and opened up a new way better to solve the large-scale structure of optimal sensor placement problem [13]. In addition, the research and application of structural safety aspects of comprehensive evaluation and decision-making, such as Wu, GU Chong, Shen proposed and developed a medium build a machine based on the Four Dam Safety Comprehensive Appraisal Expert System, the system pattern recognition and fuzzy evaluation, inference engine through an integrated, comprehensive call for Siku, the quantitative and qualitative analysis combined to achieve dam safety status online real-time analysis and comprehensive evaluation [14]. Currently, the system has been used in our Danjiangkou Dam and LONGYANGXIA Gutianxi dam, which provides a timely assessment of the security system for the dam [15]. Both some of the existing methods of research and practice in terms of damage detection methods, scholars opened up some new way. Eg due to bridge structural health monitoring with real-time and data volume characteristics, Guo Jian have put forward an application of two real-time test data separately wavelet decomposition and reconstruction method for the expression of signal characteristics, and defines a damage indication coefficients [16]. Some scholars have proposed their new methods, such as Professor Deng Julong issued a "gray system control problems," a paper in 1892, the creation of gray system theory [17]. In high-rise building health research monitoring methods Despite some progress, but the technology is still very immature [3]. Currently, most of the building structure to monitor the use of domestic mainly used in the construction phase [18]. Also, with some scholars such as Wang Juandeng [19] cultural heritage building health monitoring system, a number of studies.

Structural damage identification is the core of structural health monitoring, at present, structural damage identification method according to the main structure for the monitoring can be divided into the overall law and local law, by way of damage identification method can be divided into static and dynamic law. Overall method which will structure as is a system of mass, stiffness, damping and other physical parameters of the composition, and the structure of its physical parameters monitored by systematic research, the current overall method includes dynamic fingerprint analysis, model updating and system identification , neural networks, genetic algorithms and wavelet analysis method. Local law mainly dependent on the power of modern technology, the use of certain instruments of quantitative indicators to analyze the internal structure. Currently, local law mainly visual inspection method, staining, indentation method, rebound, ultrasonic pulse method, radiation method, magnetic particle method [20]. Wavelet recognition method from the traditional Fourier analysis, in order to solve the traditional Fourier analysis capabilities of local produce poor. Overseas Research on wavelet analysis earlier, in 1982 JOStromberg to construct the first close small Bo Jiji, But at the time it did not cause people's attention. 1986 Meyer constructed the first real Meyer wavelets base and proposed the idea of multi-scale analysis. Later M allat proposed a multi-resolution analysis of the concept, and the establishment of Mallat algorithm of wavelet theory to the study of the algorithm makes multi-directional applications in many fields [21]. In the 1990s wavelet study abroad several times to form a research boom, wavelet research is in the 90s of the last century began to study, and in 1990 with the relevant papers published publicly. Our research in the wavelet to wavelet research-based, and wavelets on the use of digital image processing accounted for a substantial proportion [22]. Wavelet analysis is a way to put the data, function or operator is decomposed into different frequency components of the tool, in large structures (such as bridges) vibration condition monitoring, the wavelet analysis relative to other ways to reduce the number of sensors. After some time on the vibration point on some of the complex structure corresponding wavelet decomposition reaction of the vibrational state can be the entire structure. Thus, wavelet analysis is applied to the vibration monitor real time online.

While traditional theory of health monitoring method is perfect, and by the piezoelectric sensors, light barriers when health monitoring sensor accuracy is very high, in terms of measurement variability can achieve accuracy of hundredths of a millimeter, but there are also small measurement range, the measurement process sensor loss, poor durability [23]. In addition, traditional health monitoring system large and complex bridge monitoring system as an example to our country, in general, a detection system consists of at least 50, as many as more than 300 sensor points, whose cost accounts for the total cost of the bridge 0.5 about%, while health monitoring system installation costs can account for about 10 percent of the entire system [24]. The machine vision with a non-contact method of monitoring, adaptability, economic, easy to operate, etc., help to overcome the shortcomings of traditional monitoring methods, development potential. In addition, people cannot reach or hard to reach places, machine vision of health monitoring method with respect to the conventional method has great advantages.

The first image processing technology produced in the 1920s to produce in the newspaper industry, was just a simple image compression, but it also can greatly reduce the time to transfer the image [25]. Digital image processing technology can be applied to other areas, such as medical, aviation and other aspects of development in the 1960s thanks to the computer. Began in the 1970s, due to the development of computer technology and artificial intelligence research, people began to study the use of a computing system image analysis method, this method is similar to people to get information from the image, called machine vision [26] . Subsequently, in 1977 the Massachusetts Marr proposed computational theory of machine vision; the theory has become a guide in the 1980s in the field of machine vision research theoretical framework [27]. Mid-80s, machine vision theories flourish, digital image processing technology developed to compress the image conversion from the beginning of time image, image enhancement, image restoration, image edge enhancement, image segmentation and other techniques [28].

The scope of the current study and application of machine vision systems are very extensive. In the industrial inspection, in the 1980s, Canada Diffracto company installed a laser system for detecting auto welding and assembly is qualified, its precision can reach 0.1mm [29]. In the medical X-ray, CT detection, traffic areas for vehicle identification in the field of satellite remote sensing for environmental monitoring, Geodetic [30]. In agricultural production, machine vision technology can be used to grow crops to detect, analyze its growth status and degree of damage; can be used to identify the quality of agricultural products, by digital image processing techniques to analyze the color, surface defects, etc. to evaluate its quality; can also be used for agricultural Harvest regard, in 1991, Japan "Kubota, 'the company has successfully developed a robot for the orange harvest, the robot can automatically identify ripe oranges in the natural environment, the accuracy rate up to 75% [31]. Although the machine vision technology has been applied to many areas, but not yet widely practiced law, including both technical imperfections of reasons, more important is the machine vision system efficiency depends on the efficiency of digital image processing algorithms, and the algorithm is not old at home and abroad method to solve many practical problems, and new algorithms are still a lot of theoretical research stage [32]. In terms of the use of civil engineering, foreign countries have begun to make some achievements, but China is still in the research stage. In 1996, Scott will Photography Measurement techniques applied to soil mechanics tests, using digital image correlation method for measuring the success of a strain of soil under stress state distribution [46]. Tongji University YF Ji et al. 2008 also published a related paper, the use of photography Measurement indoors cantilever vibration test done in the external force, by measuring the displacement method, measure its natural frequency, and on a cable-stayed pedestrian bridge to do the appropriate tests, the successful measure its natural frequency [33]. Currently, the domestic health monitoring in machine vision is still in the research stage, the contents of the study to identify and measure the main crack, in recent years there have been many achievements. Zhejiang University leaves precious as et al. [34] using the self-programming on the analog cracks (length 100mm, width 3.60mm) identify measurement error is only 1.6% of its width. In addition, the use of digital image processing techniques to measure the actual number of cracks, the crack width is greater than when the comparison of the results with the data 0.4mm crack width gauge measured, the error can be controlled within 10%. Thus, digital image processing technology which has a certain accuracy, to meet the requirements of engineering practice.

Central South University Weijun et al [35] measured the crack image processing to analyze key issues of an engineering beam and wall cracks actual measurements. This measurement requires only a digital camera and a tripod, and the results maximum error of between 3% to 16% (Note, the width of the crack is measured 0.21mm ~ 1.21mm).

Comparison of Southeast University Nie Honglin, Hu Wu-sheng [36] With each use ruler, cracks and Digital Image Processing Technology in Nanjing in the Ming Dynasty city wall crack monitoring carried out, and the results of the three methods detected by the line. Among them, the digital image processing technology by way of a digital camera and tripod free access point data acquisition, image processing by matlab7.0 programming, measure the width of the walls of cracks. The results of crack width ruler measuring the resulting digital image processing, the result crack observation instrument measurements were compared, the average difference between positive and negative ruler measuring only 0.08mm, and crack meter average difference of plus or minus 0.06mm. More single research domestic and foreign health surveillance in machine vision with respect to its contents and a wider range, and many achievements have been applied to the actual project.

Ioannis Brilakis and Lucio Soibelman [37] studies the use of machine vision surveillance methods to monitor construction, with the image processing method of the construction site transfer of picture identification, performance assessment materials materials. ZhiQiang Chen and Tara C.Hutchinson [38] using digital image processing techniques to satellite images of Iran Bam region 6.6 earthquake occurred in 2003 after the analysis, using a new edge detection method for earthquake damage assessment of urban structures.

2. Math Model

Wavelet transform is a method of time-frequency analysis of a very good, it has a very widely used in digital image processing, such as image compression, image enhancement, wavelet de-noising, image matching, feature extraction, edge detection. We will be using wavelet analysis crack image processing, build recognition model, which is mainly applied to the wavelet decomposition and reconstruction method.

2.1 One-dimensional Continuous Wavelet Transforms

We define the continuous wavelet transform as follows

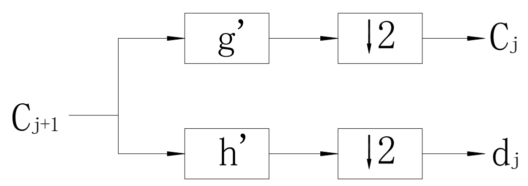
In the formula (1), we called mother wavelet or tolerance Xu Xiaobo, where the wavelet transform scale factor, displacement factor. In signal processing, continuous wavelet transform effect is actually the signal into a binary function elements become, it can be said that the signal in the wavelet decomposed into different frequencies, similar to the role of physics in the white Mitsubishi mirrors decomposition into different colors of light.

2.2 Discrete Wavelet Transform

Since the computer is used in digital processing mode, we need to implement the wavelet analysis in a computer requires a continuous wavelet transform discrete, in addition, discrete can also reduce and eliminate the redundancy of one-dimensional wavelet transform coefficients. Generally can scale factor or displacement factor discrete processing. In discrete displacement factor, for example, so that, in practice often take you, you can obtain the following discrete wavelet transform

Discrete wavelet transform is shown in Figure 1

Figure 1: One-dimensional discrete wavelet



In the above decomposition, we called the approximate sequence, known details sequences and are high-pass filtered output and low-pass filtered output, and represents down sampling operator, by discrete wavelet transform can decompose the signal into high-frequency and low-frequency part section. By wavelet decomposition we can extract the required part, reconstructed, reconstruction principle and contrary decomposition principle.

2.3 D wavelet transform

The difference is that the signal is a two-dimensional image scaling function, we can decompose by a one-dimensional in both directions through the line is completed, the decomposition process is shown below

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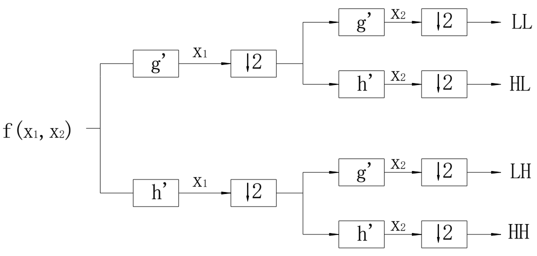
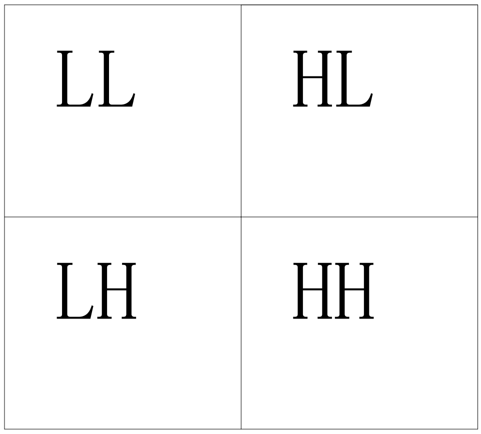
Figure 2: Dimensional wavelet decomposition



Among them, the two-dimensional wavelet decomposition of the image twice, first for the direction, the second direction. Is defined herein as an image in the horizontal direction, the vertical direction, L represents low frequency, H represents high frequency. During the decomposition process, because we use the image of the operator second extraction, resulting in post-processing the image size becomes the original image, the image-level results can be obtained by decomposing the image expressed in the following figure: 3

Figure 3: An exploded image



Similarly, the images can be multi-level exploded, Figure 4 shows an exploded view of two crack 5. schematic exploded.

Figure 4 image two decomposition

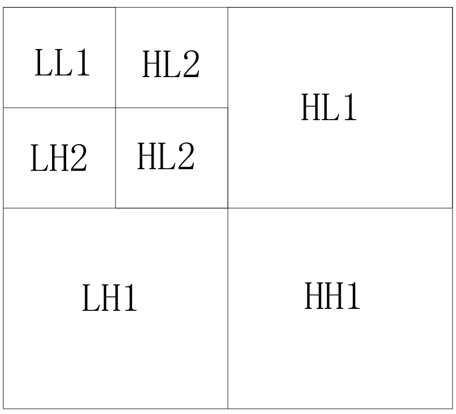
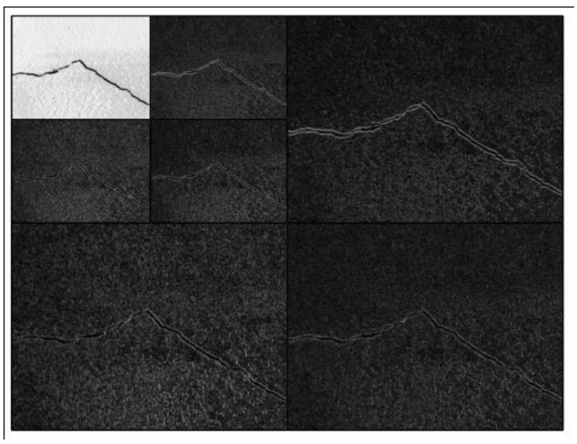


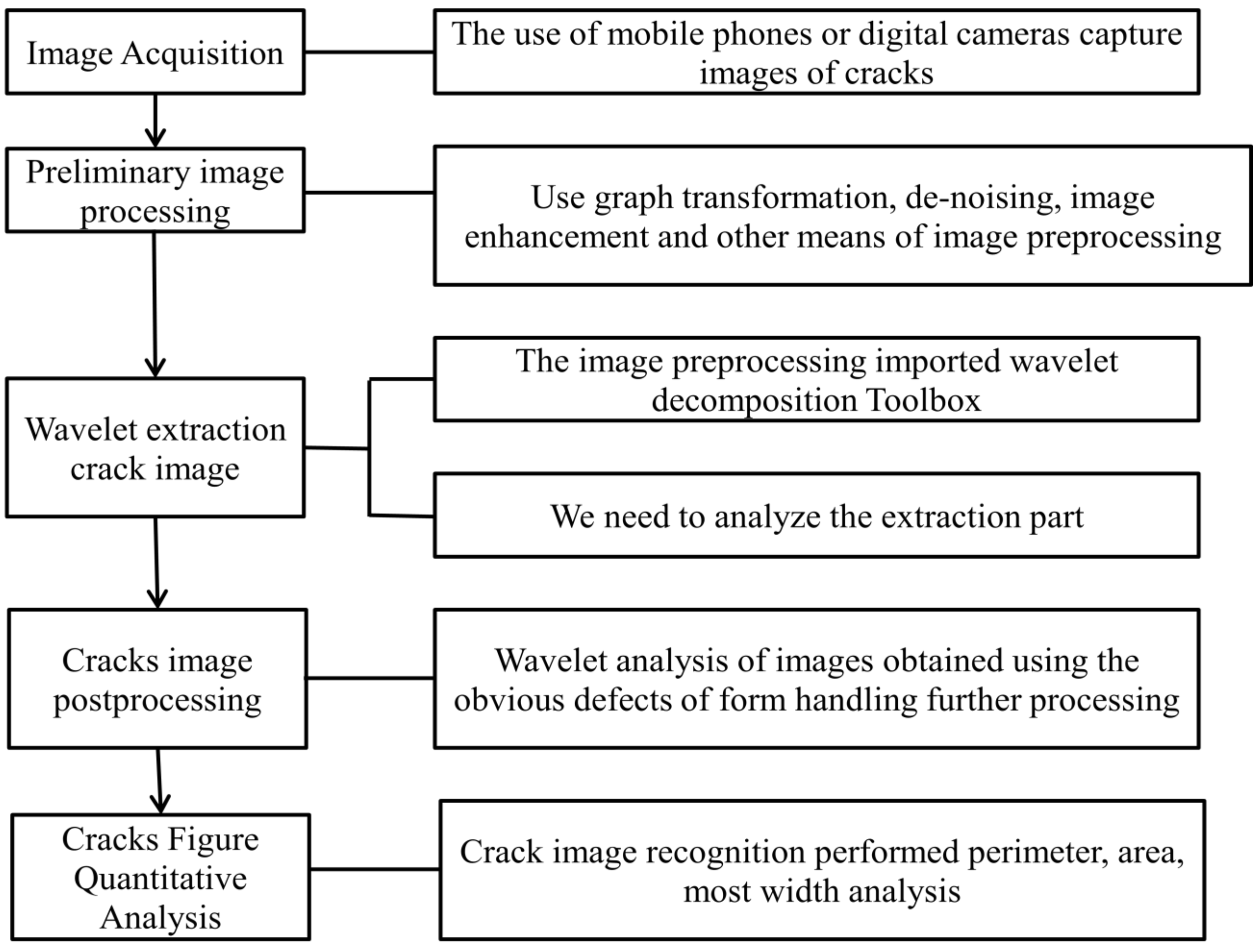
Figure 5 image two Effectiveness



3. Fracture identification based on wavelet analysis model

In this section, mainly using matlab Wavelet toolbox in the original fracture decomposition, and then extract the corresponding part of the analysis. It also needs to be extracted from the original image or an image some image enhancement, image denoising, and some morphological processing, the entire workflow general procedure shown in Figure 6, a method which uses a specific image corresponding to the different, wherein image pre-processing and post-processing is not necessary, in this section will be on some of the important steps below explain in detail.

Figure 6: Schematic model



4. The initial image processing

Original image on your phone or digital camera acquisition, since the image is true color image capture, processing in matlab served to convert it to grayscale images, for on the other hand, since the image itself contains a lot of noise, will wavelet recognition effect have some impact, we can first of the original image denoising results shown in Figure 7, 8, 9, 10.

Figure 7: Original Image

Figure 8: Binary Picture

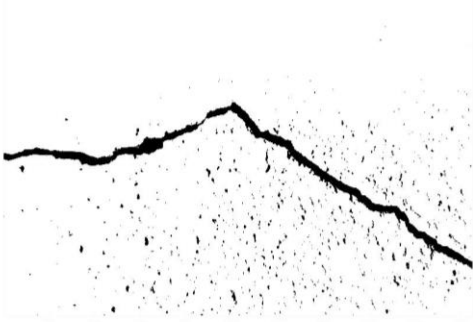


Figure 9: Wavelet Denoising Image

Figure 10: Binary Wavelet de-noising

4.2 Wavelet Decomposition

Preprocessed image, we can use some of the features in matlab Wavelet toolbox crack image decomposition in matlab wavelet toolbox can choose a variety of wavelet decomposition several times, its principle, see Section 4, and then extract desired part. In this experiment exploded through practice taking first image, that diagram (5.4) in the marquee part of the process 11 and 12.

Figure 11: Wavelet Decomposition Toolbox

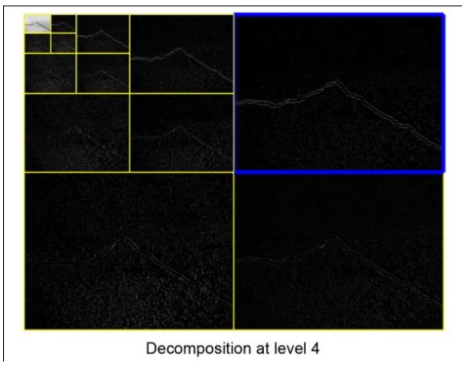


Figure 12: Extracts part of the Decomposition

Wavelet extracted from the image by image because it is gray, in order to facilitate quantitative analysis, can make some binarization, negated the operation, some of the cracks in the wavelet identified other issues there is not a continuous image can also be some form treatment, treatment results in Figure 13, 14, 16.

Figure 13: On Wavelet image

Figure 14: Binary Image

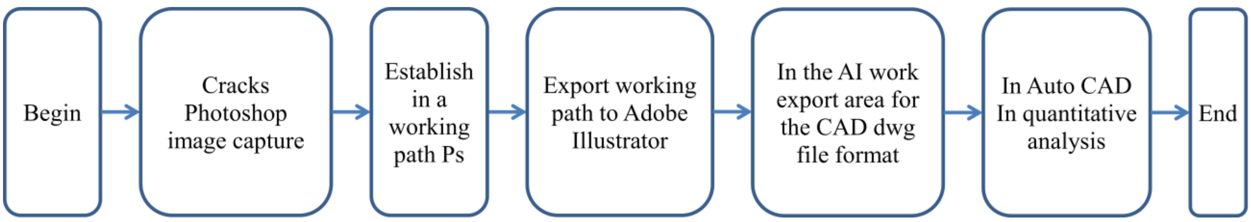
Figure 15: Binarization Negated

Figure 16: Expansion Erosion Image

4.4 Quantitative Analysis Image

After matlab image processing in order to study their difference with the original image, and image is obtained some information such as cracks length, width, etc., we need to quantify the processed image; in this experiment we are mainly to be crack width and area analysis, flow chart 17.

Figure 17: Quantitative Analysis flowchart



Throughout the quantitative analysis process, you first need to extract the cracks (cracks or original) in photoshop (referred to as PS) carried matting, and conducting error artificial matting selected when the original image analysis as a standard, other original image contrast after the image processing and analysis. After selecting the constituency to constituency converted into the working path, and export to Adobe Illustrator (abbreviated AI), as shown in Figure 18.

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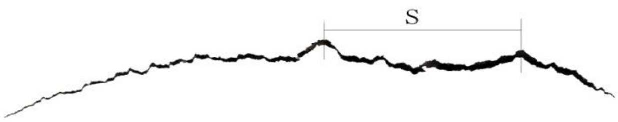
Figure 18: Importing AI Cracks Roadmap

Finally, we will export the AI path for the DWG format, in the Auto CAD in the quantitative analysis of the crack. Since the original and extracted crack FIG sample sizes, and in the PS and AI in image analysis are in pixels, in theory, the first decomposition extract the image size should be 1/4 of the original image, but taking into account during operation cause some image information is lost in this selected based on a scale to determine the proportion of original and processed after certain length feature points of the image. In Figure 19, for example, can break point after two pictures and identify the figure as a proportion of the ratio of the crack distance after picture and image processing. Practice has proved that after processing the image with the original image ratio is generally less than 0.25, which is generally close to 0.2412.

Figure 19: Schematic Feature Points



In addition, we also need to find a scale and the actual image pixel size; the proportion of pixel values is also some special points by actual distance corresponding to the distance determined.

4.5 Crack Test Analysis

In this section, the author of crack for a number of different forms of experiment process and the results are shown below in order to facilitate analysis of the experimental results below 1 unit length = 1 pixel, and not converted into units of length used in peacetime .

Experiment 1: Differences in Treatment

In this experiment, to investigate the effect of different treatments on when the cracks, this experiment Figure 7 crack test, first take haar wavelet decomposition function of crack recognition four times, and then the different post-processing, processing Figure 8-13 shows the effect of the results of each step of treatment was recorded in Table 1.

Table 1: Treated Differently Analysis Table

No	Treatment	Area	Perimeter	Dmax
0	Standard	3228.90	1341.78	14.40
1	Extract	3486.91	1318.21	15.14
	Error (%)	7.99	1.76	5.13
2	Binarization	3586.56	1329.81	15.17
	Error (%)	11.08	0.89	5.35
3	Binary negated	3586.55	1329.82	15.17
	Error (%)	11.08	0.89	5.35
4	Expansion of corrosion	4541.68	1321.90	16.39
	Error (%)	--	1.48	13.8

NOTE: D'Max represents the maximum width of crack

It should be noted that the last step is to establish the basis of the previous step. In this experiment, mainly through the line binarization, binarization negated, the expansion has corrosion treatment, the post-processing of the source as follows

```
BW1= imread('X.jpg');
H=im2bw (BW1, 0.5);
I=256-H;
Subplot (131),imshow(BW1);title('Original image');
SE1 = strel ('diamond', 7);
J = imdilate (I, SE1);
Subplot (132), imshow (J); title ('expanded image');
SE2 = strel ('disk', 4, 4);
K = imread (J, SE2);
Subplot (133), imshow (K); title ('after the first expansion of corrosion image')
```

In fracture identification process, crack wavelet analysis has identified a very high accuracy, in this experiment directly with the crack wavelet recognition of its accuracy in the area, perimeter, and width of aspect can achieve accuracy were 92.01%, 98.28 %, 94.87%. Some post-processing mode, such as binary image processing, the image is negated operation, enabling an appropriate increase in the accuracy of the image, as shown in Table 1 in terms of the accuracy of the perimeter to improve a lot, and image post-processing to facilitate our further the study. However, the image processing is not so easy to form, in the cracks of the test process, I tried a variety of ways, it is similar to solve some discontinuity, the noise of the type of problems, but it will cause some in the process new problems, so accuracy is low.

Experiment 2: Select the Effects of Different Wavelet

The main purpose of the experiment 2 is to study the effect of selection Cracking identify different wavelet function, in this experiment, choose a different image 20 crack extracted wavelet function, decomposition level are four. After the result of the establishment in terms of the line of work after binarization path will bring a lot of convenience, can reduce human error, therefore, in this experiment, I use directly after extraction and binarization as a direct result of the recognition result, the expansion of corrosion results for the post-processing result image 21, results shown in Table 2.

Figure 20: Test Crack 2 Picture

Figure 21: Wavelet Recognition Crack

Table 2: Wavelet Analysis

No.	Wavelet function	Direct identification			Post-processing		
		Area	Perimeter	Dmax	Area	Perimeter	Dmax
0	standard	1962.82	1219.39	7.24	--	--	--
1	Sym2	2284.13	1246.75	6.87	1547.47	1015.52	6.27
	Error (%)	16.37	2.24	5.11	21.16	16.72	13.39
2	haar	2291.59	1395.39	7.23	1872.06	1187.69	6.75
	Error (%)	16.75	14.43	0.14	4.62	2.60	6.77
3	demy	2308.14	1264.65	7.41	1848.67	1195.08	6.76
	Error (%)	17.59	3.71	2.34	5.82	1.99	6.62
4	db-1	2301.01	1398.32	7.23	1880.08	1185.00	6.75
	Error (%)	17.23	14.67	0.14	4.22	2.82	6.77
5	Coif2	2302.22	1257.49	7.43	1850.81	1190.47	6.75
	Error (%)	17.29	3.12	2.62	5.71	2.37	6.77

NOTE: D'Max represents the maximum width of crack

Cracks in the test identification process, selecting different wavelet function to identify cracks in which poor Sym2 wavelet recognition effect, lead to considerable error. Despite the effect of the other wavelet difference, but the difference is not very obvious, after identifying cracks in the area of respect despite larger error, but in girth and width recognition can achieve high accuracy, the width can be controlled in terms of a fundamental error within the pixel length.

Experiment 3: Different levels of the same wavelet decomposition function

The main purpose of the experiment 3 is to study choose the same wavelet function, the effects of different levels of decomposition were to identify the effect of the crack, in this experiment, the image 22 using haar wavelet function were 2,4,6,8-level decomposition, the choice after binarization result is a direct result of recognition, choose the expansion of corrosion after the results for the post-processing result image 23, results shown in Table 3.

Figure 22: Test crack 3 Picture

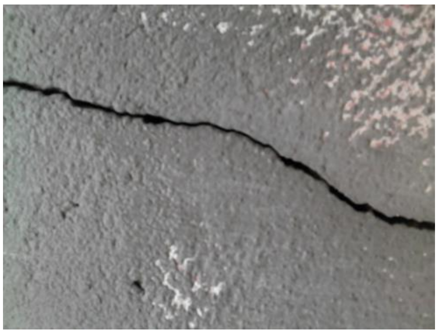


Figure 23: Wavelet Recognition

Table 3: Different Levels of the Same Wavelet Decomposition

No	Break down level	Direct identification			Post-processing		
		Area	Perimeter	D max	Area	Perimeter	D max
0	standard	2475.97	1279.40	9.88	-	-	-
1	Level2	3151.38	1438.71	11.58	2690.77	1225.49	10.37
	Error (%)	27.28	12.45	17.21	8.68	4.21	4.96
2	Level4	3151.26	1438.70	11.60	2690.77	1225.43	10.37
	Error (%)	27.27	12.45	17.41	8.68	4.22	4.96
3	Level6	3151.38	1438.71	11.58	2690.77	1225.49	10.37
	Error (%)	27.28	12.45	17.21	8.68	4.21	4.96
4	Level8	3151.38	1438.71	11.60	2690.77	1225.49	10.37
	Error (%)	27.28	12.45	17.41	8.67	4.21	4.96

NOTE D'Max represents the maximum width of crack

In wavelet decomposition process, due to cracks experiments were first extracted partial decomposition stage, decomposition level and thus had little impact on the accuracy of the identification. It is worth noting that the test crack crack 3 with other biggest difference lies in its image acquisition is collected after the rain, due to direct rainwater makes wavelet analysis identified other cracks crack relative error is large, but after it by post-processing still able to get good accuracy, especially in terms of precision area is much higher than other tests cracks.

4.6 Actual Cases

Cracks on image analysis section only is extracted as a reference manual, and its length in pixels for the unit. In this section, we selected two cracks in facades wall art library (Figures 24, 25) for the actual measurement, select multiple control points (26, 27) measuring the crack width and crack width and image processing to give scale measurements were compared. Since the fracture morphology is relatively simple, it did not crack processing of morphology, only to later identify binarized wavelet cracks as the measurement value, the comparison results are shown in Table 4 and 5.

Table 4: Test crack 4 results

Control Point	1	2	3	4
Actual (mm)	4.2	2.5	5.5	5.7
Measurement (pixels long)	10.44	5.65	14.47	15.07
Measurement Converter (mm)	4.0	2.16	5.54	5.77
Error (%)	4.76	13.6	1.09	1.23

NOTE: Scale Pixel Length = 1mm 2.61

Table 5: Test crack 5 results

Control Point	1	2	3	4	5
Actual（mm）	2.0	1.8	1.7	1.5	1.3
Measurement (pixels)	6.11	4.93	4.34	4.22	3.28
Measurement Converter (mm)	2.17	1.75	1.54	1.50	1.17
Error (%)	8.5	2.78	9.41	0	10

NOTE: Scale Pixel Length = 1mm 2.81

Although the error is greater individual control points, the control points are mainly smaller crack width point. In fact, not difficult to understand, at the same pixel error situation, the greater the crack width smaller error. For most of the control points to achieve good accuracy, and its accuracy can be maintained at substantially more than 90%.

In the actual project we need to find a reference to crack image to determine the relationship between the pixel and the actual size, and this reference is not difficult to choose. To measure the beam crack, for example, reference can be selected beam width or beam higher, as long as the crack image contains beam width or beam width and other information, it is easy to build a scale, which measured the crack-related information, significant savings in manpower and resources. In addition, we also found through the practice of using wavelet analysis is simple to operate, for a lot of cracks requires only a simple recognition can achieve high accuracy, this can reduce the late programming. Finally, in the wavelet choice difference different results due to the selection of wavelet analysis was not particularly evident in the actual operation generally do not need to consider the use of that kind of wavelet to analyze, or you can use two or three different kinds of wavelet analysis, the Results difference within a certain range can be considered as the recognition result is valid. Even if not very professional engineering and technical personnel knowledge, it is possible to operate, which is undoubtedly conducive to practical engineering application practice. Thus, the wavelet analysis has great potential for development and application prospects.

5. Conclusions and Outlook

Has great potential for development of machine vision-based health monitoring method in inconvenience only need to reach the place by remote camera can analyze the structure of some status, saving manpower and resources. Wavelet Analysis in fracture identification has simple, small steps, calculate fast and high precision characteristics, wavelet analysis in this paper, through the cracks of different wavelet analysis, the following conclusions

1. The use of crack wavelet analysis identified with high accuracy, in terms of the crack width measurement accuracy can reach 1 to 2 pixels, able to meet the needs of practical engineering application.
2. For the effect of crack image processing depends first on the clarity of the image itself. Outline a clear, better image contrast relatively easy to identify it, and the error is smaller. Pixel image containing a large amount of information, greater accuracy, but its operation is slower.

3. In recognition function wavelet choice to select a different function in spite of some differences, but the difference in fracture identification process is not great.

4. Although the fracture identification process can solve some problems like discontinuity, the use of appropriate post-processing approach can improve the accuracy of image recognition, but it can also produce some new errors. Under the conditions meet the accuracy, identify patterns as simple as possible, the number of image processing, the better.

Although wavelet identified cracks can have a good accuracy, and can identify a variety of cracks, but there are many problems, where you can make some follow-up research prospects as follows

1. The wavelet analysis research has a single, continuous cracks have good recognition results, but more for the number of cracks, fractures form a complex image recognition results are not satisfactory, you can follow this regard.

2. Although the crack width and girth error is very small, but in terms of the error area is still quite large, and post-processing of large cracks extract difficulty in this regard is a research direction.

3. This is due to technical problems and time, in the course of quantitative analysis is to study the physical characteristics of the crack plane that crack width, perimeter, area, and did not go to study spatial characteristics cracks, cracks and other information such as depth, Crack spatial characteristics is also the direction of future research.

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