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Content-Based Image Retrieval System for Optical Fiber Sensor Information Processing

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Abstract*—Fiber reinforced polymer (FRP) materials are finding new application areas every day. Monitoring of FRP materials is essential to make the structure fail-safe. Researchers have developed many methods for structural health monitoring (SHM) of FRP structures by using optical fiber sensors. The interrogation system used for processing optical fiber sensor information in these SHMs is very complex and expensive. In this regard, a unique interrogation method has been emphasized in this paper. Proposed work involves in developing the interrogation system, with the aid of content-based image retrieval (CBIR) using MATLAB.

Keywords—Content-based image retrieval system, fiber reinforced polymer, optical fiber sensors, structural health monitoring.

I. Introduction

Fiber reinforced polymer (FRP) composites have been successfully used as an engineering material in many areas such as aircraft, aerospace, automobiles, pipeline due to its superior strength-to-weight ratio. The mechanical behaviour of the FRP composites will be significantly different from the conventional materials. Structural health monitoring (SHM) is definitely essential to enhance the safety of these composite structures during service condition. Hence the response of these FRP composite structures for the applied loads, temperatures need to be continuously monitored. Smart materials and structures provide the real possibility of SHM on-line and in place. Fiber optic sensors are very important sensors that are used in smart materials and structures. Embedded optical fiber sensors are the most widespread sensors for measuring the in-service mechanical parameters of the fibrous composite structures.

Fiber optic sensors have been used for SHM of composite structures for many years due to their advantages such as small diameter, light weight, flexibility, high sensitivity, non-electric and the immunity to the electromagnetic interference (EMI). Fiber optic sensors such as fiber Bragg grating (FBG) sensors are employed in the cure monitoring and the non-destructive evaluation of composite materials [4]. Mingyao Liu et al. [5] have been reported the use of FBG sensors for identifying the damage location in plate like structures, by measuring the strain frequency response functions from intact and damage state. The application of FBG sensors has also extended to the SHM of aerospace structures [6]. Geert Luyckx et al. [3] and Yoji Okabe et al. [7] have successfully used embedded FBG sensors to measure internal strain and investigated the change in spectral shapes and change in strain in the vicinity of the damage.

In all these works regarding the SHM using fiber optic sensors, the interrogation employed is generally the wavelength scanning and other various interferometric approaches. In this proposed work an attempt towards interrogation of fiber optic sensor using content-based image retrieval (CBIR) system is successfully made. CBIR is a process of retrieving a similar image from database by supplying an image as a query. CBIR finds its application in different areas such as military, optical character recognition, biometrics, medical diagnosis. Kalyanroy et al. [9] have worked on retrieving the similar image from database using color histogram, color coherence vector and Manhattan distance methods. Similarly MettyMustikasari et al. [10] have used Euclidean distance and city block distance methods for measuring the similarity of images.

In this paper, a unique method for interrogation of the fiber optic sensors using CBIR system has been proposed. The optical fiber sensor is embedded in FRP laminate and one end of the sensor is coupled to a laser source. During the training of the CBIR system, a number of images of the other end of the sensor are captured at different known temperatures and these images are stored in a database. Then an image of the same end at some unknown temperature is captured and this image is queried into the database, so that the result is the extraction of the similar image from the database. Hence this finally results in monitoring the temperature of the FRP structure using optical fiber sensor along with CBIR system during the service condition.

II. CBIR system

CBIR means extracting a range of images from a database which are similar to the given image. The basic CBIR system is shown in the Figure 1. The first step in CBIR system is to extract the features of images. Some of the important features of an image are color, shape, texture, etc. Then these features are stored in the database. Now the same features of the query image are extracted and the similar images are retrieved by employing suitable similarity measurement algorithms.

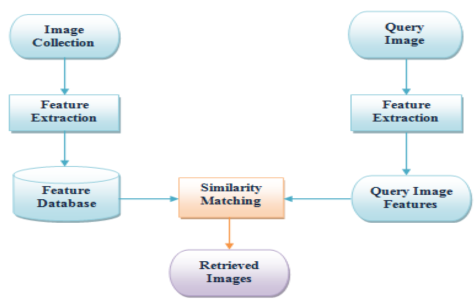

Figure 1 Basic CBIR system

III. Proposed method

The optical fiber sensor is embedded in FRP laminate by positioning it directly between the plies during hand layup fabrication technique and one end of the optical fiber is coupled to the laser source. The other end is continuously monitored by a webcam. Figure 2 shows the schematic illustration of the proposed setup. A 5MP web camera is used for capturing the sensor tip images. The wavelength of the laser source is 650 nm and the detailed specification is given in table 1. Figure 3 shows the tip of the optical fiber sensor at a certain temperature captured from a webcam. A number of such images at different known temperatures are captured and the color feature of these images is extracted. The feature extracted here is histogram of the HSV (Hue, Saturation and Value) image.

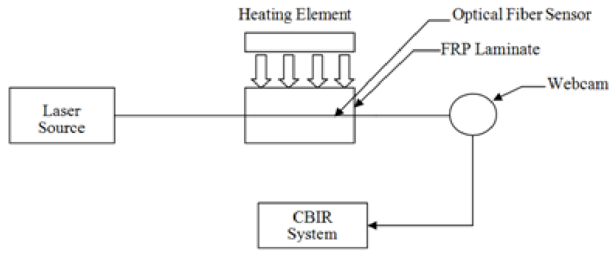

Figure 2 Schematic illustration of proposed set up

The extracted features of all the images are stored in a database and the same feature is extracted from the query image.

Table 1 Specification of laser source

Model	Pen type visual fault locator
Emitter	Laser diode
Wavelength	650±10nm
Output power	1MW, 3MW, 5MW, 10MW, 15MW
Transmission distance	Depending on the output power
Working mode	CW & modulation
Modulation	1Hz, working cycle:60%
Connector	2.5mm universal connector
Power	2pcs AA battery
Operating temperature	-10ºC~+50ºC
Storage temperature	-20ºC~+70ºC
Weight	162g
Length x diameter	185 x 25mm
Working hours	10mw continuous work ≥ 20h

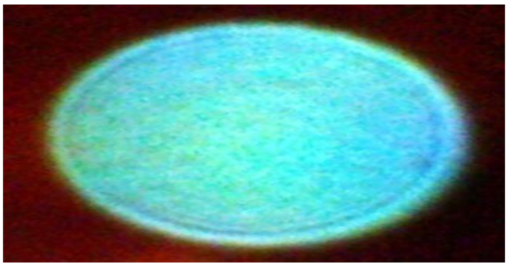

Figure 3 Tip of optical fiber sensor

Then, the similarity measurement is done using the Euclidean distance method for retrieving the similar images. The flowchart of the proposed CBIR system is shown in Figure 4.

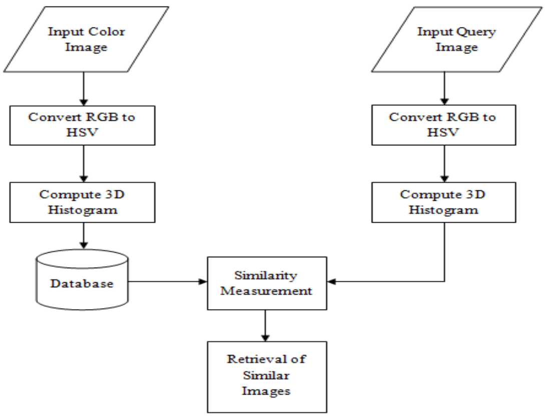

Figure 4 Proposed CBIR system

IV. HSV Histogram Analysis

Hue, Saturation, Value or HSV is a color model that describes colors (hue or tint) in terms of their shade (saturation or amount of gray) and their brightness (value or luminance). Figure 5 shows the typical HSV color space. Image histogram is a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value.

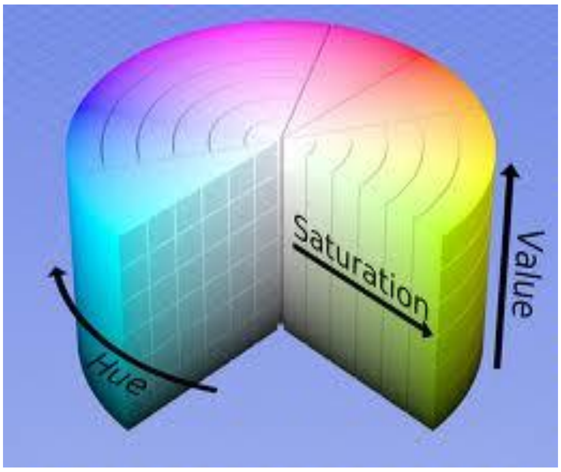

Figure 5 HSV color space

The histogram of HSV images is extracted and stored in a database using the procedure shown in Figure 6. 100 images at different known temperatures are used in this analysis.

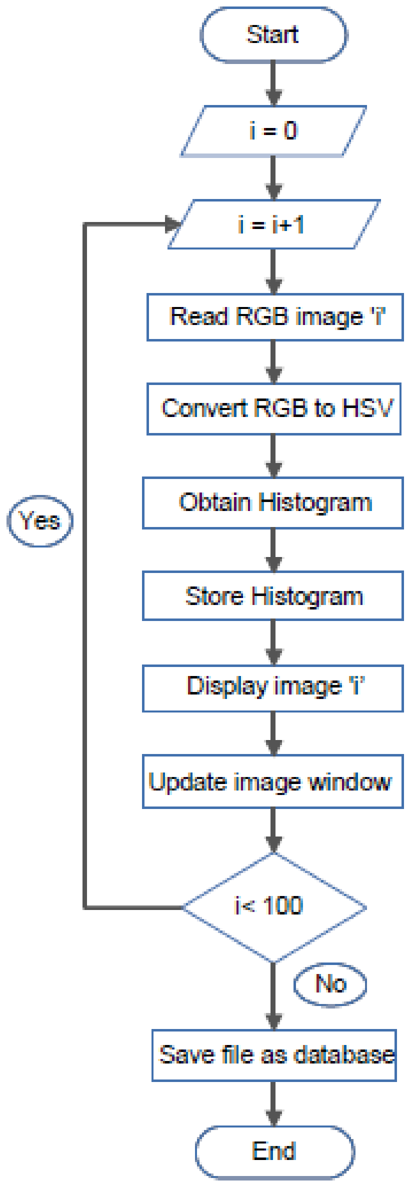

Figure 6 Flow Chart of Histogram Analysis

V. Similarity measurement using the Euclidean distance method

A global color histogram represents an image I by an *N*-dimensional vector, **H** *(I)* = [**H** *(I, j)*, *j* = 1, 2, . . . , *N*], where *N* is the number of quantization colors and **H**(*I*, *j*) is the number of pixels having color *j* . The similarity of two images can be easily computed on the basis of this representation. The most widely used method for similarity measurement is the Euclidean distance method. It is the spatial distance in a multi-dimensional space. Equation (1) is the formula used for computing the Euclidean distance between the query image and the database image.

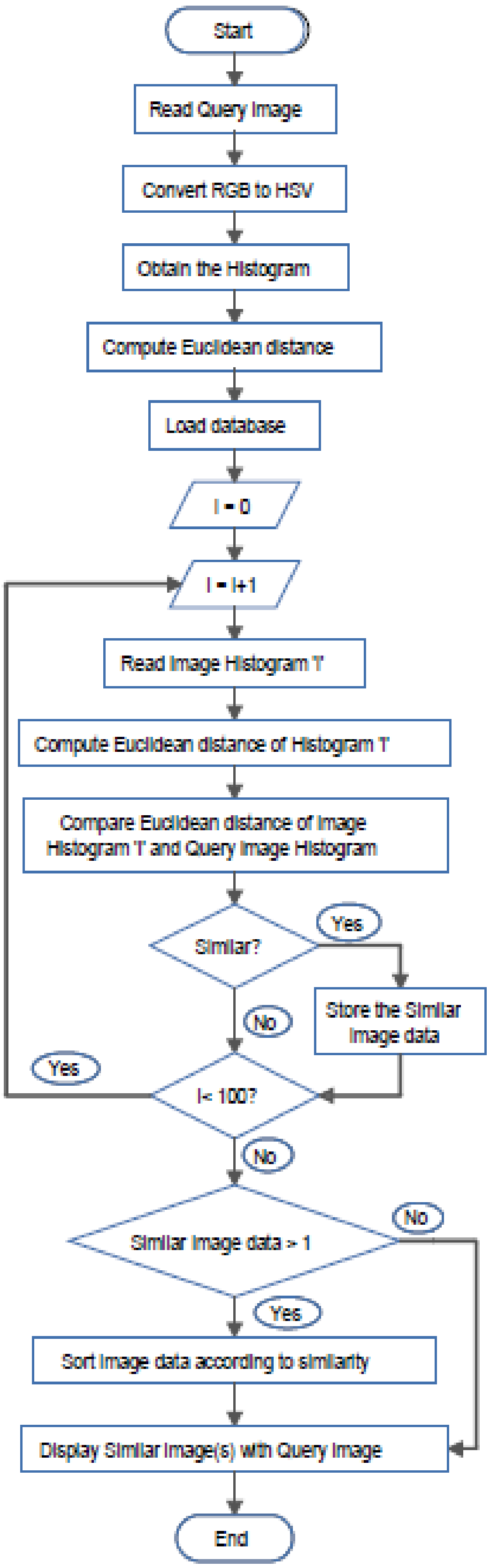

Figure 7 Flow chart of Similarity Measurement

Figure 7 shows the flow chart of measuring the similarity between the query image and the images in the database.

$$D(q,b) = \sqrt{\sum_{h=1}^{m}\sum_{s=1}^{n}\sum_{v=1}^{p}[q(h,s,v) - b(h,s,v)]^2} \quad (1)$$

The query image is first converted to HSV image and its histogram is obtained. Then the Euclidean distance of this query image is computed. The next step is to load the database and compute the Euclidean distance for all the images in the database. Now the comparison is made between the query image distance and to those that of in the database. Then the similar images are retrieved and sorted according to similarity.

VI. Results and Discussions

The retrieval of the most similar image from the database using CBIR system is successfully carried out.

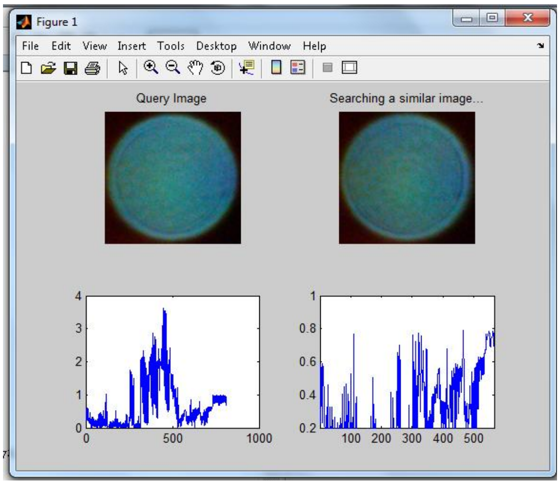

Figure 8 Searching similar image

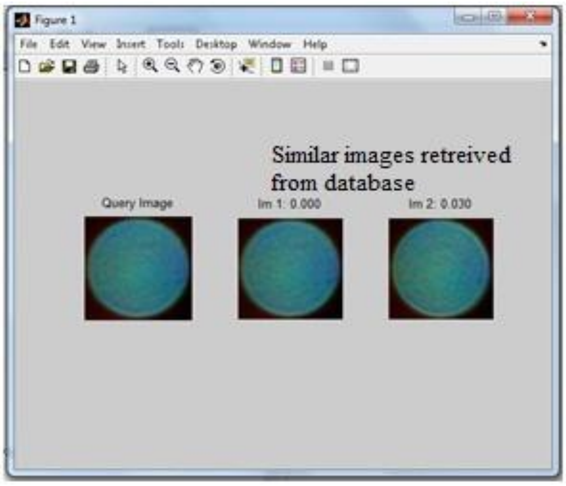

Figure 9 Result of similar images

The process of searching a similar image by measuring the similarity using Euclidean distance method is shown in Figure 8. Figure 9 shows the images which are similar to the query image. This shows that the temperature of FRP structure at which the query image was captured is similar to that of the temperature at which the Im 1 was captured as shown in Figure 9.

VII. Conclusion

In this paper, CBIR interrogation system for optical fiber sensor based SHM is developed successfully. A number of images of optical fiber sensor tip at different known temperatures are captured and stored in the database. Any query image at some unknown temperature is captured and similarity measurement is performed. This result in retrieving the most similar image from the database so that one can determine the unknown temperature based on the temperature of a retrieved image.

VIII. Future work

This proposed method can be applied to monitor the different mechanical parameters of FRP structures using optical fiber sensor. Manhattan distance, Chebyshev distance or some other similarity measuring methods can be used. Still more images at different temperatures can be used in the database. Furthermore, other features of the image can be extracted for more accurate results.

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