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THE DEVELOPMENT OF AN Φ-OTDR SYSTEM BY USING 2D QUANTITATIVE METHOD

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Abstract-This paper presents an edge detection method has been proposed to extract the location information of intruder in the distributed vibration sensing system based on phase sensitive optical time domain reflectometry. The edge detection method is used to calculate the spatial gradient of the image composed by Rayleigh traces at each point by convolving with Sobel operator. Hence the amplitude fluctuation of Rayleigh backscattering traces induced by external vibration can be located. The SNR of location information increases to as high as compared to conventional method, where the effect of noise is reduced by local averaging within the neighbourhood of mask. The spatial resolution could be also optimized from 5m to 3m when 50ns pulse is launched into the single mode fiber with 1km length. The sensing system has the potential to extract available signals from the hostile environments with strong background noise.

I.INTRODUCTION

Fiber optical vibration sensors have attracted a significant research attention and got extensive applications in many fields in recent years due to their immunity to electromagnetic interference, flexibility, compactness, and economy. Up to now, fiber optical vibration sensors mainly consist of point and distributed sensors. Several schemes of point sensors including fiber gratings Fabry-Perot interferometers and fused-tapered optical fiber couplers have been demonstrated to realize the vibration measurement with a high sensitivity to external strain, whereas it requires a prior knowledge of potential faults. Distributed fiber sensors have the capability of detecting intrusion with long perimeters or wide areas compared to point sensors. Optical parameters such as light intensity, phase, polarization state and light frequency will change when external perturbation is applied to the sensing fiber. Hence distributed vibration sensing systems based on phase-sensitive optical time domain reflectometry (Phase OTDR) polarization OTDR and stimulated Brillouin scattering have been proposed. As one of most important distributed optical fiber sensing techniques, phase-OTDR has been widely used in practice, due to its high sensitivity to intruder, multipoint detection, and no frequency drift for detection.SNR of location information will increase in a certain range as the increase of element value near the central point. Sobel operator is used to rapidly highlight the difference between points. If the amplitude change of vibration points is abrupt, it is worth to increase the element value to improve the effectiveness of the two-dimensional edge detection method. However, if the amplitude change of non-vibration points is also rapid, or even faster than vibration points, SNR of location information would be deteriorated by increasing the elements.While traditional image search engines heavily rely on textual

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words associated to the images, scalable content-based search is receiving increasing attention. Apart from providing better image search experience for ordinary Web users, large-scale similar image search has also been demonstrated to be very helpful for solving a number of very hard problems in computer vision and such as image categorization.

II.OPTICAL TIME DOMAIN REFLECTOMETRY

An optical time domain reflectometer (OTDR) is a precision instrument used to locate events or faults along a fiber link, typically within an optical communications network. The OTDR launches a series of high speed optical pulses into the fiber to be measured. Various events on the fiber generates a Rayleigh back scatter that returns to the OTDR and the strength of the return pulses are measured and integrated as a function of time, and plotted as a function of fiber length. The horizontal axis is the distance and the vertical axis is the loss. OTDRs are mainly used in the optical fiber installation and maintenance servicing of access networks (communications links between telephone exchanges and telephone poles) and user networks (communications links between user sites and telephone poles).An OTDR trace helps characterize individual events that can often be invisible when conducting only loss/length testing. Only with a

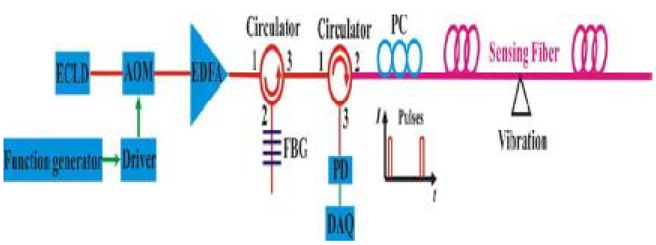

Fig. 1. Schematic of Φ-OTDR system.ECDL, external-cavity diode laser; AOM, acoustic-optic modulator; EDFA, erbium doped fiber amplifier; circulator; PD, photon detector; DAQ, data acquisition.

complete fiber certification, installers have the most complete picture of the fiber installation and network owners have proof of a quality installation.

The light source is an external cavity laser with ultra-narrow line width of less than 50 KHz and maximum output power of 10 mW. The optical light is then modulated into optical pulses with 80 MHz frequency shift induced by acoustic optical modulator (AOM), which is controlled by an arbitrary function generator. An erbium-doped fibre amplifier is utilized to amplify the pulses and the spontaneous emission noise is filtered by a fiber Bragg grating. Then pulses are gated into the sensing fiber (Corning SMF- 28e) with 1 km length through an optical circulator. Rayleigh backscattering 22 light is detected by a photo detector (PD). Then Rayleigh backscattering traces are sampled by an acquisition card with 100 MHz sampling rate. A Lab view computer program is developed for vibration tests to measure the location information.

A. External Cavity Diode Laser

Semiconductor diode lasers are widely used in modern technology because of their compactness, low cost, and durability. However, diode lasers have two major drawbacks. Light emitted by a diode laser is not monodirectional and typically has a large bandwidth. While collimating the output of a diode laser is a relatively simple problem to solve with lenses, narrowing the bandwidth of the output requires construction of an external cavity. In this project create an external cavity diode laser (ECDL), which selects a

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single wavelength from the entire output spectrum of the diode laser and drives the laser at this wavelength. Thus, by using optical feedback from a diffraction grating, we are able to narrow the total bandwith emitted by the diode laser. We have characterized the tuning of this laser and show how the laser can be used to conduct research and also teach the fundamentals of laser physics and semiconductor applications.

B. Acousto-optic modulator

Acousto-optic modulators (AOMs) are useful devices which allow the frequency, intensity and direction of a laser beam to be modulated. Within these devices incoming light Bragg diffracts off acoustic wavefronts which propagate through a crystal. Modulation of this incoming light can be achieved by varying the amplitude and frequency of the acoustic waves travelling through the crystal.

C. Erbium Doped Fiber Amplifier

An erbium amplifier, also called optical amplifier or an erbium-doped fiberamplifier or EDFA, is an optical or IR repeater that amplifies a modulated laser beam directly, without opto-electronic and electro-optical conversion. The device uses a short length of optical fiber doped with the rare-earth element erbium. When the signal-carrying laser beams pass through this fiber, external energy is applied, usually at IR wavelengths. This so-called pumping excites the atoms in the erbium-doped section of optical fiber, increasing the intensity of the laser beams passing through. The beams emerging from the EDFA retain all of their original modulation characteristics, but are brighter than the input beams.This amplifier is used to boost optical signals to higher power, often used both at launch and within a signal network to maintain a high signal power. The amplifier is based on erbium doped fiber, and can be incorporated directly into an optical network, avoiding the need to convert optical signals to electrical signals for amplification and re-launch. The fiber is pumped at 980nm to excite erbium ions in the fiber, these will add gain to a signal as the ions are stimulated to emit by an optical signal at around 1550nm passing through the fiber.

D. Circulator

In fiber optical networks passive components such as optical isolators are essential for delivering of signals with minimum loss. Another type of passive element that is commonly used in fiber optic systems is the optical circulator. These devices that are used to direct the optical signal from one port to another port and in one direction only. This action prevents the signal from propagating in an unintended direction. Optical circulators have continued to increase their presence in a broad array of applications, including optical amplifiers, optical add and drop systems, dense wavelength-division multiplexing (DWDM Mux) networks and, optical time domain reflectometers.

E. Function Generator

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine, square, triangular and sawtooth shapes.

F. Driver

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A device driver is a small piece of software that tells the operating system and other software how to communicate with a piece of hardware.

G. Fiber Bragg Grating

A fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others.Fiber-optic sensors have been developed to measure co-located temperature and strain simultaneously with very high accuracy using fiber Bragg gratings.A fiber Bragg grating is a periodic or aperiodic perturbation of the effective refractive index in the core of an optical fiber.

H. Photo Detector

Photon detectors count photons of light. A photon detector has some surface that absorbs photons and produces some effect (current, voltage) proportional to the number of photons absorbed. Rayleigh backscattering light is detected by a photo detector (PD)

I. Data Acquisition

Data acquisition (DAQ) is the process of measuring an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound with a computer. A DAQ system consists of sensors, DAQ measurement hardware, and a computer with programmable software. Compared to traditional measurement systems, PC-based DAQ systems exploit the processing power, productivity, display, and connectivity capabilities of industry-standard computers providing a more powerful, flexible, and cost-effective measurement solution.DAQ cards often contain multiple components (multiplexer, ADC, DAC, TTL-IO, high speed timers, RAM). Data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Equipment ranges from simple recorders to sophisticated computer systems, or even smart phones turned into portable data acquisition systems.

III. PROPOSED SYSTEM

To extract location information of intruder in the distributed vibration sensing system based on phase-sensitive optical time domain reflectometry. The edge detection method is used to calculate the spatial gradient of the image composed by Rayleigh traces at each point by convolving with Sobel operator, hence the amplitude fluctuation of Rayleigh backscattering traces induced by external vibration can be located. The signal to noise ratio of location information based on the method increases to as high as 8.4 dB compared to conventional method, where the effects of noise are reduced by local averaging within the neighbourhood of mask. The spatial resolution could be also optimized from 5 m to when 50 ns pulse is launched into the single mode fibre with 1 Km length. The sensing system has the potential to extract available signals from the hostile environments with strong background noise.

A. Peak to Signal Noise Ratio

The phrase peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is most commonly used as a measure of quality of reconstruction

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of lossy compression codecs (e.g., for image compression).

It is most easily defined via the mean squared error (MSE) which for two *m*×*n* monochrome images *I* and *K* where one of the images is considered a noisy approximation of the other is defined as:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

The PSNR is defined as:

$$PSNR = 10.\log_{10}\left(\frac{MAXi^2}{MSE}\right)$$
$$=20.\log_{10}\left(\frac{MAXi}{\sqrt{MSE}}\right)$$
$$=20.\log_{10}(MAXi) - 10.\log_{10}(MSE)$$

Where,

MAXi = maximum possible pixel value of the image.

B. Threshold Technique

Threshold technique is one of the important techniques in image segmentation. This technique can be expressed as:

T=T[x, y, p(x, y), f(x, y] …………(1)

Where,

T = threshold value,
x, y = coordinates of the threshold value point,
p(x,y), f(x,y) =points the gray level image pixels,

Threshold image g(x,y) can be define:

g(x,y) = {1 if f(x,y)>T
0 if f(x,y)<=T

FIVE THRESHOLD TECHNIQUES:

1. Mean Technique:

This technique used the mean value of the pixels as the threshold value and works well in strict cases of the images that have approximately half to the pixels belonging to the objects and the other half to background. This technique case rarely happens.

2. P-Tile techniques

The p-tile technique uses knowledge about the area size of the desired object to the threshold an image. The P-tile method is one of the earliest threshold methods based on the gray level histogram. It assumes the objects in an image are brighter than the background, and occupy a fixed percentage of the picture area. This fixed percentage of picture area is also known as P%. The threshold is defined as the gray level that mostly corresponds to mapping at least P% of the gray level into the object. Let n be the maximum gray level value, H (i) be the histogram of image (i = 0. n), and P be the object area ratio.

The algorithm of the P-tile method is as follows:

S=sum (H(i)) (3)
Let f=s
For k=1 to n
f=f-H(k-1)
If (f/t) <p then stop
T=k

Where,

S= total area of image
f= initialize all area as object area
T= final Thersold value

This method is simple and suitable for all sizes of objects. It yields good anti-noise capabilities; however, it is obviously not applicable if the object area ratio is unknown or varies from picture to picture.

3. Histogram Dependent Technique (Hdt):

The histogram based techniques is dependent on the success of the estimating the threshold value that separates the two homogenous region of the object and background of an image. This required that, the image formation be of two homogonous and will-separated regions and there exists a threshold value that separated these regions. The (HDT) is suitable for image with large homogonous and will separate regions where all area of the objects and background are homogonous and except the area between the objects and background.

This technique can be expressed as:

C (T) =P1 (T)σ12(T) +P2(T)σ22(T) (4)

Where,

C (T)=within-group variance,

P1 (T)=probability for group with values less than T,

P2(T) =probability for group with values greater than T,

σ1 (T) =variance of group of pixels with values less than or equal to T,

σ2 (T)=variance of group of pixels with values greater than T.

4. EMI Technique:

The threshold image by using edge maximization technique (EMT) is used when there are more than one homogenous region in image or where there is a change on illumination between the object and its background. In this case portion of the object may be merged with the background or portions of the background may as an object. To this reason any of the automatic threshold selection techniques performance becomes much better in images with large homogenous and well separated regions. This techniques segmentation depend on the research about the maximum edge threshold in the image to start segmentation that image with help the edge detection techniques operators.

5. Visual Technique:

These techniques improve people's ability to accurately search for target items. These techniques are similar to one another P-Tile technique in that they all use the component segments of original images in novel ways to improve visual search performance but it is different from p-tile don't active when the noise is present in the image.

C. Spatial Resolution:

Spatial resolution is the density of pixels over the image: The greater the spatial resolution, the more pixels are used to display the image.

Halve the size of the image:

It does this by taking out every other row and every other column, thus leaving only those matrix elements whose row and column indices are even.

Double the size of the image:

All the pixels are repeated to produce an image with the same size as the original, but with half the resolution in each direction.

D. Sobel Operator

The Sobel operator, sometimes called the Sobel–Feldman operator or Sobel filter, is used in image processing and computer vision, particularly within edge detection algorithms where it creates an image emphasising edges. The Sobel operator is an algorithm for edge detection in images. The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image.

Sobel operator is a kind of orthogonal gradient operator.The gradient magnitude is given by:

$$|G| = \sqrt{Gx^2 + Gy^2}$$

Typically, an approximate magnitude is computed using:

$$|G| = |Gx| + |Gy|$$

which is much faster to compute.

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$$\theta = \arctan(Gy/Gx)$$

IV.CONCLUSION

In this project, we introduce a two-dimensional edge detection method to distributed vibration sensing system based on Phase-OTDR. The edge detection method calculates the gradient of the image composed by Rayleigh traces at each point by convolving with Sobel operator. SNR and spatial resolution of location information are investigated with different matrix sizes and different element values of Sobel operator. When pulse width is 50 ns,~3m spatial resolution and SNR of location information of 8.4 dB have been achieved by two -dimensional edge detection method, which proved to be a powerful method to enhance the performance of Phase-OTDR system. The output is shown in the form of graph as well as effects in image itself. By seeing the different effects of image, we finally came to know that the damaged fiber is in this form with respective PSNR values. This project can be efficiently identifying the dislocation in any fibre using canny operator. The peak to signal noise ratio is increased. This helps us to improve the image clarity and easily identify where the breaks exactly occurs in inside the core of a fibre. Their PSNR values also determined.

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