Optical fiber cables networks defects detection using thermal images enhancement techniques

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Abstract: - Image enhancement is a process to output an image which is more suitable and useful than original image for specific application. Thermal image enhancement includes many techniques used in Quality Control, Problem Diagnostics, and Insurance Risk Assessment. Various enhancement schemes are used for enhancing an image which includes gray scale manipulation, filtering and Histogram Equalization (HE), Fast Fourier Transform which results in Highlighting interesting detail in images, removing noise from images, making images more visually appealing, edge enhancement and increase the contrast of the image. This research article explains how could the various stated techniques and operations will be useful in the detection of the defects for the optical fiber cables and their connectors and most of optical devices to be more effective in Optical fiber based communication systems.

Key-Words: - Histogram Equalization, Linear Filtering, Adaptive Filtering, Fast Fourier Transform, 3D Shaded surface plot.

1 Introduction

Optical fibers are essential components in the modern telecommunication scenario. From the first works dealing with the optimization of optical fibers transmission characteristics to accommodate long distance data transmission until the actual optical fiber communication networks, a long way was paved. Many equipment's especially the handheld devices like 279 FC which is a full-featured digital multi-meter with integrated thermal imaging and has been designed to increase the productivity and confidence. The thermal multi-meter helps to find, repair, validate, and report many electronic issues quickly so that many of confident problems are solved. [1]

For the fiber optical cables and various types of connectors there are many equipments used to check on the items. At the working period of the cables and its connectors sometimes faults have been happened so we need another equipments like the thermal imaging hand held devices (279 FC) to check on site during the working period to not stop work at each problem.

Thermal imaging multi-meters are the first-line troubleshooting tool for electrical equipment that can check hot spots on high-voltage equipment and transformers, also detect heating of cables, insulators, connectors, splices and switches. Scanning with the thermal imager reveals many electrical issues rapidly and from a safe distance. See Fig. 1. [2]

The generated colored images from these equipments could be enhanced to produce more accurate after many processing steps to get more accurate images contains more details to determine the faults or problems is fiber cables and connectors.

The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide ‘better' input for other automated image processing techniques. Digital image processing are used in various application in medicines medicine, space exploration, authentication, automated industry inspection and many more areas.

Fig. 1. 279 FC digital multi-meter with thermal imaging scanner.

2 Optical Fiber Network defects

Fiber optic cables are reserved for high-performance needs so there are more potential causes of trouble. [3] and [4] So, here are some of the most common fiber optic cable problems with their possible causes: [5] and [6]

- Broken fibers because of physical stress or excessive bending.
- Insufficient transmitting power.
- Excessive signal loss due to a cable span, contaminated connector, faulty splices or connectors, too many splices or connectors.
- Faulty connection of fiber to the patch panel or in the splice tray.

Figs 2 and 3 explain visual examples for the surface damages for the optical fiber cables and connectors which cause many physical and communication defects in optical fiber communication systems. [7] and [8]

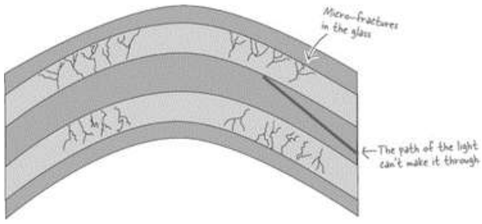
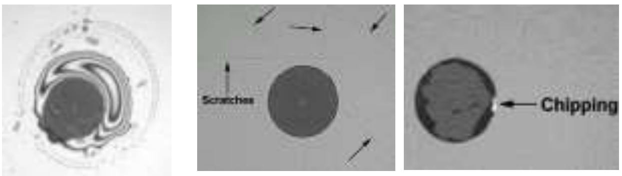


Fig. 2. Physical cracks inside the fiber cables due to hard flexion.



(a) (b) (c)

Fig. 3. Connectors defects: a) Liquid Contamination, b) Scratches, c) Chipped Cladding and Excessive Epoxy

3 Image Enhancement implementation

Image enhancement is actually the class of image processing operations whose goal is to produce an output digital image that is visually more suitable as appearance for its visual examination by a human observer. Specifically to image enhancement; the input and output digital images are grey scale or color images. So that the relevant features for the examination task are enhanced and the irrelevant features for the examination task are removed/reduced. [9] and [10]

The suggested technique is to get an output image contains details more accurate than the original thermal image to indicate the defects or the damages of the fiber optical cables or devices and components. Fig. 4. shows the suggested algorithm for the technique has been used to get the enhanced images after many image processing operations.

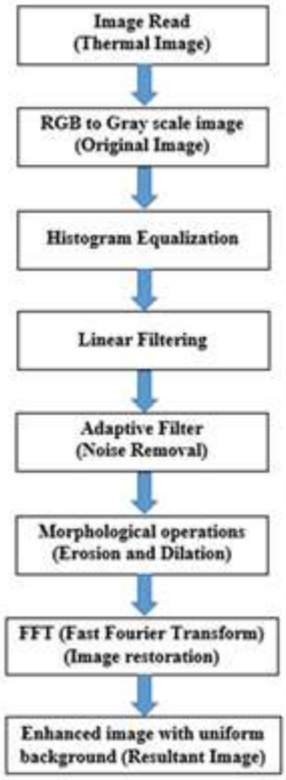
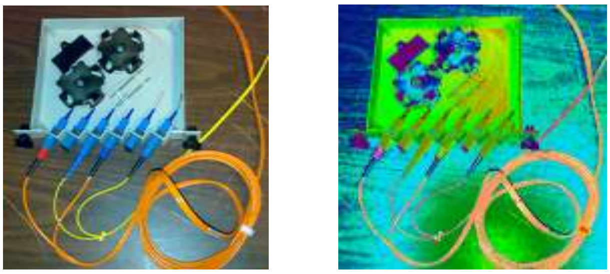


Fig. 4. Suggested techniques for image enhancement block diagram.

3.1 RGB to GRAYSCALE image conversion

In RGB images each pixel has a particular color. Such an image is a "stack" of three matrices; representing the red, green and blue values for each pixel. Whereas in grayscale each pixel is a shade of gray, normally from 0 (black) to 255 (white). [11] and [12]

Gray image takes less space in memory in comparison to RGB images. The gray image is enhanced using the histogram equalization algorithm. Figs. 5, 6, and 7 show some examples of optical fiber cables connected to various devices and components which reveals the existence of some electrical anomalies and defects.



(a) (b)

Fig. 5. Visual Inspection of optical fiber cables in an optical coupler reveals the existence of electrical anomalies (Sample 1)

a) RGB regular image and b) Thermal Image

(a) (b)

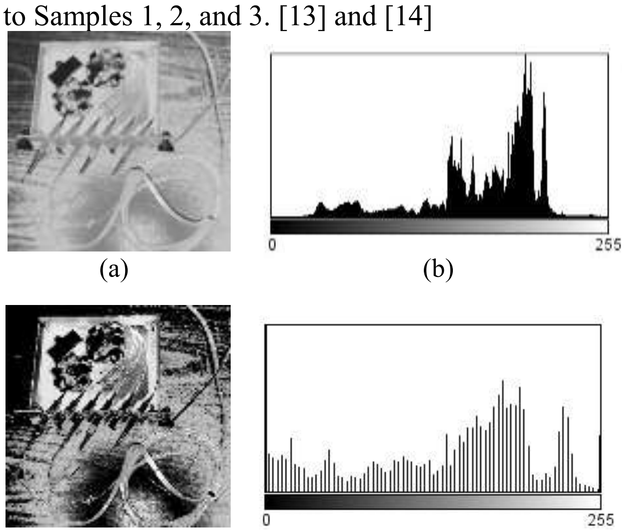
Fig. 6. Visual Inspection of optical MUX-DEMUX rear cables reveals the existence of electrical anomalies (Sample 2) a) RGB regular image, b) Thermal Image

(a) (b)

Fig. 7. Visual Inspection of optical Router-Switch cables reveals the existence of electrical anomalies (Sample 3) a) RGB regular image, b) Thermal Image

3.2 Histogram, Histogram Equalization and Contrast Enhancement

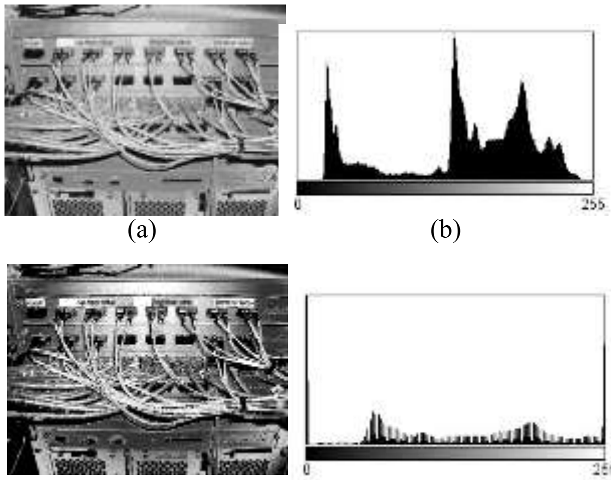
As the *histogram* of an image shows the distribution of grey levels in the image massively useful in image processing, especially in segmentation. *Histogram equalization* involves finding a grey scale transformation function that creates an output image with a uniform histogram. Contrast enhancements improve the perceptibility of objects in the scene by enhancing the brightness difference between objects and their backgrounds A contrast stretch improves the brightness differences uniformly across the dynamic range of the image. See figs.8, 9, and 10 for these purposes to Samples 1, 2, and 3. [13] and [14]



(a) (b)

(c) (d)

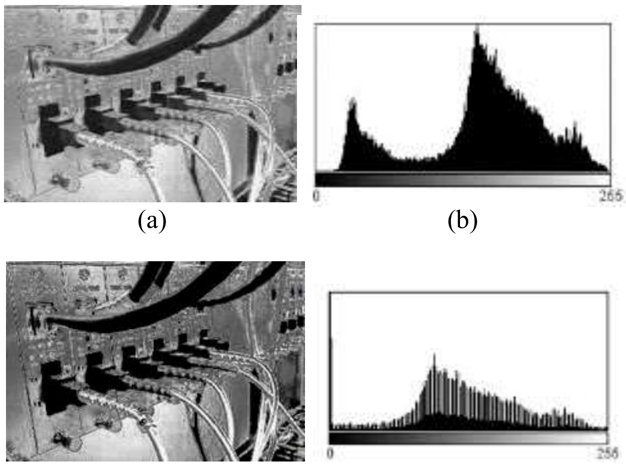
Fig. 8. Sample 1: a) Gray scale of thermal image
b) Histogram chart for (Gray scale of thermal image)
c) Histogram Equalization for (Gray scale of thermal image)
d) Histogram chart for (Histogram Equalized image)



(a) (b)

(c) (d)

Fig. 9. Sample 2: a) Gray scale of thermal image
b) Histogram chart for (Gray scale of thermal image)
c) Histogram Equalization for (Gray scale of thermal image)
d) Histogram chart for (Histogram Equalized image)



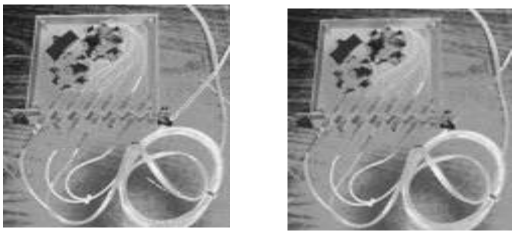
(a) (b)

(c) (d)

Fig. 10. Sample 3: a) Gray scale of thermal image
b) Histogram chart for (Gray scale of thermal image)
c) Histogram Equalization for (Gray scale of thermal image)
d) Histogram chart for (Histogram Equalized image)

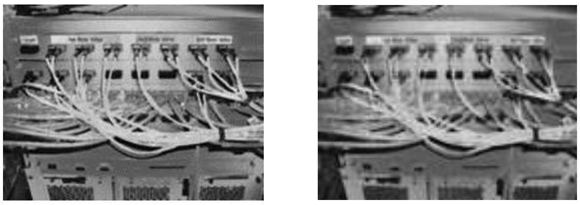
3.3 Linear Filtering and Noise Removal

Filtering is a technique for modifying or enhancing an image. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement. Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighborhood. The noise is removed by adaptive filtering approach, often produces better results than linear filtering. The adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. In figs. 11, 12, and 13 will see the images of the histogram equalized image after Linear filtering and Noise Removal using Adaptive Filter for the Samples 1, 2, and 3.



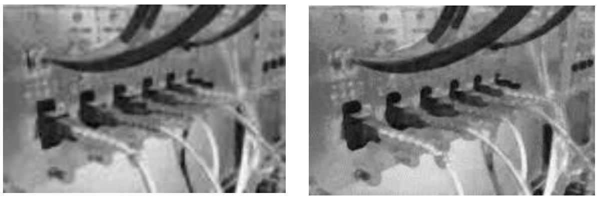
(a) (b)

Fig. 11. Sample 1:
a) Filtered image after histogram equalization
b) Noise removal image by adaptive filtering



(a) (b)

Fig.12. Sample 2:
a) Filtered image after histogram equalization
b) Noise removal image by adaptive filtering



(a) (b)

Fig. 13. Sample 3:
a) Filtered image after histogram equalization
b) Noise removal image by adaptive filtering

4 Morphology operations

The basic idea is to probe an image with a template shape, which is called structuring element, to quantify the manner in which the structuring element fits within a given image. The output from this stage will be equal to (I – B), where output is the image obtained after the removal of non-uniform background (B) from grayscale image (I) uniform background throughout the image.

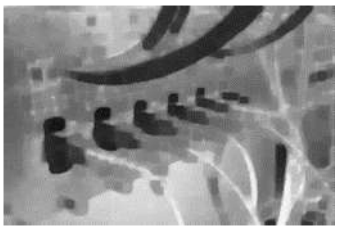
Basically the main purpose of the Morphological Image Processing is to remove unwanted artifacts in an image or to improve image's clarity. In the suggested algorithm the techniques of erosion and dilation along with the combination of Skeletonization and Perimeter determination. For image representation of objects of an image, specific set of pixels called object pixels is used. By erosion operation, the conversion of the pixels associated with the object's boundary to pixels in the background is possible, while with the help of dilation operation, the bordering background pixels can be changed to the ones that are associated with the object [15]

For implementation of image processing operations combination of dilation and erosion are mainly used, for example, the definition of a morphological opening of an image says that it is erosion which is followed by dilation, with the help of the similar structuring element for both operations. The related operation, for morphological closing of an image, is just the reverse, which consists of dilation followed by erosion with the similar structuring element.

For a pixel that is to be considered as a perimeter pixel if it satisfies both of these criteria i.e. the pixel should be on and one (or more) of the pixels in its neighborhood should be off. Fig. 14 shows the output image after morphological operations for the Samples 1, 2, and 3. [16]

(a)

(b)

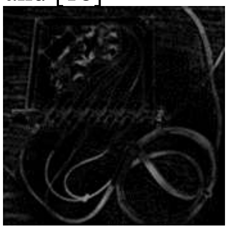


(c)

Fig. 14. Output image after morphological operations (Excessive Dilation and Erosion)
a) Sample 1 b) Sample 2 c) Sample 3

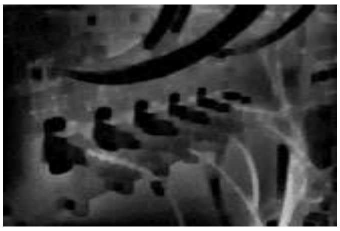
5 FFT transform

In Fourier transform it actually changes the domain of the image. In this we get the restored image after taking the inverse FFT. Therefore, the signal's spectrum should be entirely below fs/2, the Nyquist frequency. Fig. 15 shows the restored image after the FFT and IFFT processing on the morphological operations images for the Samples 1, 2, and 3. [17] and [18]



(a)

(b)



(c)

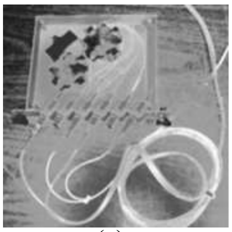
Fig. 15. Restored image after FFT and IFFT operations
a) Sample 1 b) Sample 2 c) Sample 3

6 Experimental results

The results obtained from the enhancement of the thermal images is the improvement of the image in which we get the useful information. The histogram obtained from these images is also improved which shows that image is enhanced, the intensity range is also better. The 3D shaded surface plot is also better in the morphology operation and the FFT mesh plot is only change the domain. Figs. 15, 16, and 17 show the final resultant images for each sample had been used which includes the original gray scale image for the thermal image, the histogram equalized image, the image itself after the morphological operation and also the final restored image after the FFT and IFFT processing. Figs. 18, 19, and 20 show the 3D shaded surface plot for the original gray scale image for the thermal image, the image itself after the morphological operation and also the final restored image after the FFT and IFFT processing.

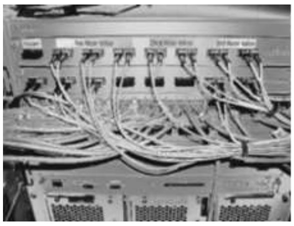
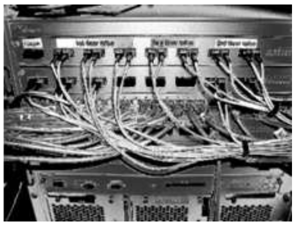
 

(a) (b)

(c) (d)

Fig. 15. Sample 1: a) Thermal image Gray scale
b) Resulting image after histogram equalization
c) Image after morphological operation
d) Restored image after the FFT transform

(a) (b)

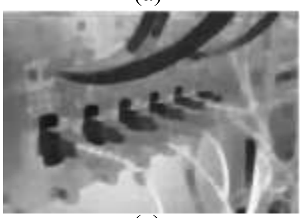
 

(c) (d)

Fig. 16. Sample 2: a) Thermal image Gray scale
b) Resulting image after histogram equalization
c) Image after morphological operation
d) Restored image after the FFT transform

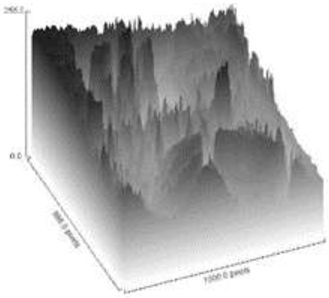
(a) (b)

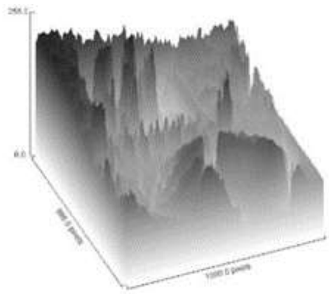
(c) (d)

Fig. 17. Sample 3: a) Thermal image Gray scale
b) Resulting image after histogram equalization

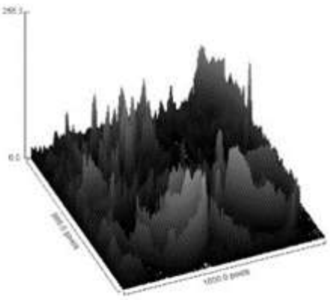
c) Image after morphological operation
d) Restored image after the FFT transform



(a)

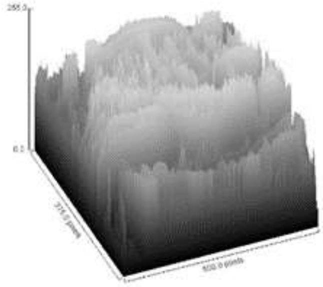


(b)

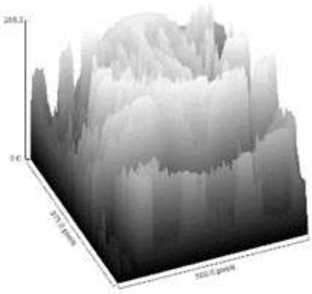


(c)

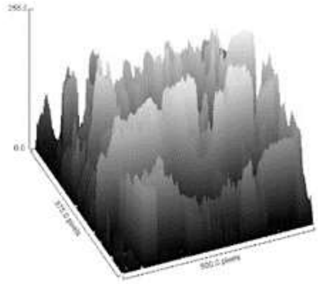
Fig. 18. 3D Shaded Surface Plot Sample 1
a) Thermal image Gray scale
b) Image after morphological operation
c) Restored image after the FFT transform



(a)

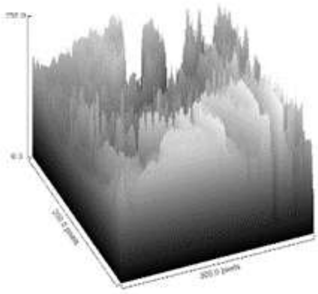


(b)

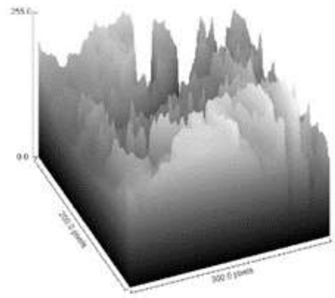


(c)

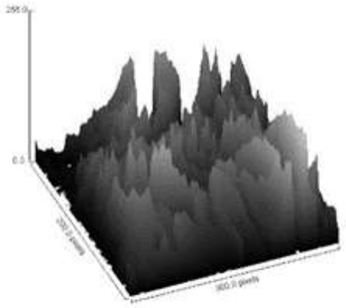
Fig. 19. 3D Shaded Surface Plot Sample 2
a) Thermal image Gray scale
b) Image after morphological operation
c) Restored image after the FFT transform



(a)



(b)



(c)

Fig. 20. 3D Shaded Surface Plot Sample 3
a) Thermal image Gray scale
b) Image after morphological operation
c) Restored image after the FFT transform

7 Conclusion

The introduced algorithm for thermal images enhancement includes many techniques. Histogram equalization technique used for images suffering from non-uniform illumination in their backgrounds specifically for particle analysis purposes as this process only adds extra pixels to the light regions of the image and removes extra pixels from dark regions of the image resulting in a high dynamic range in the output image. The images obtained after the morphology operations is much clear than the previous images which is effective in defects detection. The last stage of the introduced algorithm was FFT transform that converts the domain of the image and is necessary to enhance the thermal images for determination of defects occurred in optical fiber communication network elements.

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References:

[1] Komal Vij, et al. (2009). Enhancement of Images Using Histogram Processing Techniques. Vol 2, pp309-313.

[2] Kevin Loquin, et al. (2010). "Convolution Filtering and Mathematical Morphology on an Image: A Unified View. pp 1-4.

[3] M. Kowalczyk, et al. (2008). Application of mathematical morphology operations for simplification and improvement of correlation of images in close-range photogrammetry. pp 153-158.

[4] J. Zimmerman, S. Pizer, E. Staab, E. Perry, W. McCartney, B. Brenton. (1988). Evaluation of the effectiveness of adaptive histogram equalization for contrast enhancement. IEEE Transactions on Medical Imaging, pp. 304-312.

[5] M. Abdullah-Al-Wadud, Md. Hasanul Kabir, M. Ali Akber Dewan, Oksam Chae. (2007). A dynamic histogram equalization for image contrast enhancement. IEEE Transactions. Consumer Electron., vol. 53, no. 2, pp. 593-600.

[6] Rafael C. Gonzalez, Richard E. Woods. (2002). Digital Image Processing. 2nd edition, Prentice Hall.

[7] A. K. Jain. (1991). Fundamentals of Digital Image Processing. Englewood Cliffs, NJ: Prentice-Hall.

[8] J. Alex Stark. (2000). Adaptive Image Contrast Enhancement Using Generalizations of Histogram Equalization. IEEE Transactions on Image Processing, Vol. 9, No. 5.

[9] Dakin, Pratt. (1985). Distributed Optical Fibre Raman Temperature Sensor Using A Semiconductor Light Source And Detector. Electronics Letters 20th, Vol. 21 No. 13.

[10] M. Niklès, B. Vogel, F. Briffod, S. Grosswig, F. Sauser, S. Luebbecke, A. Bals, T. Pfeiffer. (2004). Leakage detection using fiber optics distributed temperature monitoring. Smart Struct. and Mat.: Smart Sensor Techn. and Meas.

[11] Najman, L. and Schmitt, M. (1996). Geodesic saliency of watershed contours and hierarchical segmentation, Pattern Analysis and Machine Intelligence. IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol.18, No. 12, Pp.1163-1173.

[12] Abedin, K. S. and T. Morioka. (2009). Remote Detection of Fiber Fuse Propagating in Optical Fibers. Proceedings of Conference on Optical Fiber Communication, collocated National Fiber Optic Engineers Conference Vol. 1-5, pp. OThD5, San Diego, CA, USA.

[13] Percival, R. M., E. S. R. Sikora and R. Wyatt. (2000). Catastrophic damage and accelerated ageing in bent fibers caused by high optical powers. Electronics Letters, Vol. 36, No. 5, pp. 414-416, ISSN: 0013-5194.

[14] P. Soile (2003). Morphological image analysis, principles and applications. Springer, Berlin.

[15] W. Wolberg, W. N. Street, O. L. Mangasarian. (1994). Machine learning to diagnose breast cancer from image-processed features. Rep. of Uni. Wisconsin.

[16] Matlab user manual – Image processing toolbox. (1999). MathWorks, Natick.
[17] Holst, Gerald C. (2006). Electro-optical Imaging System Performance, JCD Publishing Winter Park, Florida USA, , ISBN: 0-8194-6179-2
[18] Ulrich Kienitz. (2014). Thermal imaging as a modern form of pyrometery. Journal of Sensors and Sensor Systems, 3, 265–271.