Advanced Image Processing Technique for Failure Analysis

Smt.Maya.V. Lakha[1], Dr.S.P.RajaManohar[2], Dr. K. ChennaKeshava Reddy[3], Dr .Abdul Sattar[4]

[1]Research Scholar, ECE dept. Jawaharlal Nehru Technological University Hyderabad, T.S. India.
[2]Supervisor, ECE dept. Jawaharlal Nehru Technological University Hyderabad, T.S., India.
[3]Co- Supervisor, ECE dept. Jawaharlal Nehru Technological University Hyderabad, T.S. India.
[4]ECE dept., Royal Institute of Technology, Chevella, Hyderabad, T.S. India.

Abstract—*Failure patterns of mechanical components and materials can be observed by surface deformations. Preventive maintenance always minimizes the failure patterns and here is a method proposed which not only minimizes the failures but also analyses the life expectancy of such components and materials. Image processing using Matlab Tool Boxes is emerging as a perfect simulation platform and by writing simple codes one can see its effect which can be analyzed by ease. The paper proposes a robust image processing technique and is developed on Matlab platform.*
Keywords—*Light Interferometer, Non-Destructive Techniques, Optical NDT, Surface Deformation, SVD.*

I. INTRODUCTION

Failure analysis is thought to be finite elemental analysis as far as mechanical components and materials are considered. Added to it is non-destructive technique which ways back to 1879 and since then the topics evolved into a necessity in industry for quality, quantity analysis and valuations. Nondestructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system.

Today modern nondestructive tests are used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level. During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public.

A four step process is usually popular in the field of Structural Health Monitoring and damage detection. The first three steps are connected and involve the detection of the presence, the location and the severity of damage, while the fourth step, related to the prediction of service life is usually a separate problem by itself.

Machine vision systems provide quality control and real-time feedback for industrial processes, overcoming physical limitations and subjective judgment of humans. In this paper, the image processing techniques for developing low-cost machine vision system for surface deformation inspection is explored. By developing image processing techniques, and minimal hardware, a low-cost flexible system is developed. The system acquires the image data and this image isprocessed and then a custom classification system algorithm accepts or rejects the mechanical element or material.

II. METHODOLOGICAL SURVEY

Non-Destructive Testing (NDT) [1] is defined as the determination of the physical condition of an object without affecting that object's ability to fulfill its intended function. Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed). The methods and techniques used in NDT measure physical properties or non-uniformity in physical properties of materials as well. Variations or non-uniformities in physical properties may or may not affect the usefulness of a material, depending upon the particular application under consideration. Nondestructive testing is the testing of materials, for surface or internal flaws or metallurgical condition, without interfering in any way with the integrity of the material or its suitability for service. The technique can be applied on a sampling basis for individual

investigation or may be used for 100% checking of material in a production quality control system. The common NDT methods are:

Visual and opticalTesting: Visual inspection is particularly effective detecting macroscopic flaws.

UltrasonicTesting: This technique is used for the detection of internal and surface (particularly distant surface) defects in sound conducting materials. The principle is similar to echo sounding.

ElectromagneticTesting: The main applications of the eddy current technique are for the detection of surface or subsurface flaws.

ThermographicTesting: Infrared Thermography is the science of measuring and mapping surface temperatures.

RadiographicTesting: radiography provides a permanent reference for the internal soundness of the object.

Liquid PenetrationTesting: LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

Magnetic particleTesting: This method is suitable for the detection of surface and near surface discontinuities in magnetic material, mainly ferrite steel and iron.

Acoustic Emissiontesting: Used to measure small surface displacement of a material produced due to stress waves generated when the energy in a material or on its surface is released rapidly.

Magnetic Resonance ImagingTesting: medical imaging technique used in radiology to visualize internal structures of the body in detail.

Near-InfraredSpectroscopy: it is very useful in probing bulk material with little or no sample preparation.

Optical MicroscopeTesting: Purely digital microscopes are now available which use a CCD camera to examine a sample, showing the resulting image directly on a computer screen without the need for eyepieces.

The use of statistical pattern recognition dates from 1950s and, although it is not one of the main topics of image processing research, it provides an important background - especially in the area of automated visual inspection where decisions about the adequacy of the products have to be made constantly [2]. On the other hand, real industrial applications of texture description and recognition are becoming more and more common [3, 4]

During the last two decades, the improvement in image processing with microcomputers has caused non-contact measurement techniques to become more and more popular in the experimental mechanics community. Some full-field measurement techniques like moire´, interferometry or

photo elasticimetry were known and used beforehand. These techniques suffered however from the non-automatic processing of the fringe patterns they provided, leading to some heavy, boring and unreliable by-hand manipulations before obtaining relevant information in terms of displacement or strain. In the recent past, thanks to the dramatic advances in microcomputer and camera technology, many research groups devoted to optics, experimental mechanics or data processing have been developing suitable techniques based on the use of optical devices, digital cameras, algorithms and software's which automatically process images. These techniques directly provide displacement or strain contours onto specimens under testing. Temperature fields are also available thanks to infrared scanning cameras. Such measurements constitute in fact a new type of tool for researchers in mechanics of solids, which is especially interesting in the field of composite material characterization. Indeed, composites present some features like heterogeneities at different scales which render such full field measurements very attractive [5].

III.   PROPOSED METHODOLOGY

One of the most important problems, perhaps the most urgent from the point of view of industry productivity and competitiveness, is automatic inspection. Early detection of defects in the production means lower costs and faster feedback on the production line in order to eliminate the causes of defects, overcomes physical limitations and subjective judgment of humans. In industry, zero defect quality is highly required in competitive markets. So, a very cost effective, high throughput and reliable quality inspection method is important in the industry.

The paper proposes a robust Image processing technique [6-12] wherein the image is acquired, preprocessed, features are extracted and then test images are classified as go or no-go decision based on comparison. The preprocessing step reduces the image to a processing compatible format and the most popular and robust Singular Value Decomposition Algorithm is used to extract the image features. Classification decision is based on the comparison with standard values which are served as thresholds. Near comparison is done by using the Euclidian distance.

The various steps and the block schematics are depicted as below:
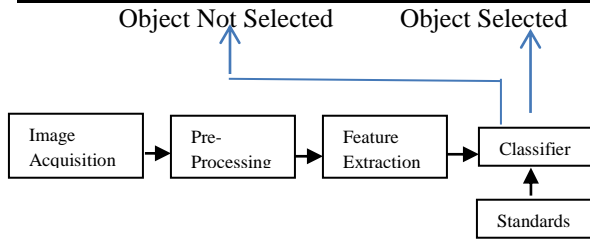
Object Not Selected   Object Selected

Fig. 1: Proposed system.

To acquire the image either Digital Camera or Phenomenon of Light Interferometer techniques are used. The image is then made processing compatible by reducing the size to 128x128 pixels, the color images are converted into gray and 3D images are converted into 2D image.

The feature Extraction Algorithm runs the Singular Value Decomposition Algorithm and calculates the S, U and V matrices. Comparing the weights of the object under test with the known weights of the standards performs identification. Mathematically, a score is found by calculating the Euclidian norm of the differences between the test and known set of weights, such that a minimum difference between any pair would symbolize the closest match**.**The classifier gives out select or reject as the output.

IV.   ALGORITHM AND SIMULATION RESULT

Singular Value Decomposition (SVD) is statistical tool and found application in digital image processing since it is assumed that every image matrix is having a well-known SVD. It is based upon covariance matrix property to reduce image dimensions. The dimension of the data is reduced by finding a few orthogonal linear combinations of the original variables with the largest variance. The singular value decomposition is an outcome of linear algebra. It plays an interesting, fundamental role in many different applications. One such application is in digital image processing. SVD in digital applications provides a robust method of storing large images as smaller, more manageable square ones. This is accomplished by reproducing the original image with each succeeding nonzero singular value. Furthermore, to reduce storage size even further, images may approximate using fewer singular values [17- 20]

The singular value decomposition of a matrix A of m x n matrix is given in the form,

$$A = U\Sigma V^T$$ ------------- (1)

Where U is an m x m orthogonal matrix; V an n x n orthogonal matrix, and Σ is an m x n matrix containing the singular values of A along its diagonal.

$$\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_n \geq 0$$ ------------ (2)

An SVD operation breaks down the matrix *A* into three separate matrices.

$$
\begin{aligned}
A &= U\Sigma V^T \\
&= [u_1 \ldots u_n] \begin{bmatrix} \sigma_1 & & \\ & \cdots & \\ & & \sigma_n \end{bmatrix} \begin{bmatrix} v_1^T \\ \vdots \\ v_n^T \end{bmatrix} \\
&= [u_1 \ldots u_n] \begin{bmatrix} \sigma_1 v_1^T \\ \vdots \\ \sigma_n v_n^T \end{bmatrix} \\
&= \sigma_1 u_1 v_1^T + \ldots + \sigma_n u_n v_n^T
\end{aligned}
$$

$$= \sigma_1 u_1 v_1^T + \ldots + \sigma_r u_r v_r^T$$

Because

$$\sigma_{r+1} \ldots \sigma_n =$$ are equal to zeros.

The center matrix known as the diagonal matrix which can be treated as a defect indictor.

For result simulation let us consider a mechanical object viz., tire with no surface deformation and one with deformation.

Case 1: Tire with no deformation:
Original Query Image

Fig. 2: Tire Image with no deformation

The algorithm classifies the query image as selected and generates its related Singular Values which are in close proximity with the standards

60.962	0	0	0	0	0
0	15.402	0	0	0	0
0	0	7.6051	0	0	0
0	0	0	6.7205	0	0
0	0	0	0	4.2795	0
0	0	0	0	0	4.0941

Fig. 3: Generated singular values for query image 1

Case 2: Tire with Deformation

Original Query Image

Fig. 4: Tire Image with deformation

The figure shows the tire with surface deformation and the SVD algorithm classifies it as not selected and generates its singular values which are far below the standards.

65.503	0	0	0	0	0
0	17.69	0	0	0	0
0	0	9.5787	0	0	0
0	0	0	7.5057	0	0
0	0	0	0	6.7604	0
0	0	0	0	0	4.8269

Fig. 5: Generated singular values for query image 2

V. CONCLUSION

Image processing aspects in this paper and in general are seen as pattern recognition problem. Much of the work on non-destructive techniques particularly in the area of failure analyses of mechanical or for that matter any industrial product is largely based on heavy testing equipment's or methods but, this paper proposes a more reliable and easy process through which one can assess the usefulness of the material or the element under question quickly. Light interferometry or shearography combined with Image processing can be useful for analyzing the mechanical aspects of the material or the elements.

REFERENCES

[1] Fein, H. (1997), "Holographic Interferometry: Non-destructive tool". The Industrial Physicist, American Institute of Physics.

[2] E. Davies, Machine vision: theory, algorithms, practicalities. Morgan Kaufmann, 2005.

[3] M. Egmont-Petersen, D. Ridder, and H. Handels, "Image processing with neural networks - a review", Pattern recognition, vol. 35, pp. 2279-2301, 2002.

[4] M. Sonka, V. Hlavac, and R. Boyle,"Image Processing, Analysis, and Machine Vision", Brooks/Cole Publ., 1999.

[5] Michel Gre´diac, "The use of full-field measurement methods in composite material characterization: interest and limitations", Composites: Part A 35 (2004) 751–761, Elsevier.

[6] Pan, B., Qian, K., Xie, H., Asundi, A. (2009), "Two-dimensional digital image correlationfor in-plane displacement and strain measurement: A review.Measurement", Sci. andTech.,20(6), 1−17.

[7] Sutton, M.A. (2008), "Digital image correlation for shape and deformation measurements", Handbook of Experimental Solid Mechanics. New York: Springer.

[8] Sutton, M.A., Orteu, J.J., Schreier, H.W. (2009). DIC, "Image Correlation for Shape, Motion and Deformation Measurements: Basic Concepts, Theory and Applications". New York: Springer, 83.

[9] Giachetti, A. (2000), "Matching techniques to compute image motion". Image Vis. Comput., 18, 247−260.

[10] Sutton, M.A., Orteu, J.J., Schreier, H.W. (2009). DIC, "Image Correlation for Shape, Motion and Deformation Measurements: Basic Concepts, Theory and Applications". New York: Springer, 95.

[11] Chu, T.C., Ranson, W.F., Sutton, M.A., Peters, W.H. (1985), "Applications of digital image correlation techniques to experimental mechanics, .Experimental Mechanics, 25(3), 232−244.

[12] Glover, C., Jones, H. (1994), "Stress, strain and deformation in solids. Conservation Principles of Continuous Media". Texas: McGraw-Hill.

[13] Guo, X., Liang, J., Xiao, Z.Z., Cao, B.B. (2014), "Digital image correlation for large deformation applied in Ti alloy compression and tension test". Optik, 125(18), 5316−5322.

[14] Mathworks, Integral Image. (2012). mathworks.com/help/vision/ref/integralimage.html

[15] McNeill, S.R., Sutton, M.A., Miao, Z., Ma, J. (1997), "Measurement of surface profile using digital image correlation", Experimental Mechanics, 37(1), 13−20.

[16] K.R Mak P. Peng and H.YK. Lau, "A real time computer vision systems for detecting defects in textile fabrics", IEEE International Conference on Industrial Technology, pp. 469-474, 2005.

[17] Z. Hong, " Algebraic feature extraction of image for recognition,"*Pattern Recognition",*24 (1991) 211–219.

[18] Y.Tian, T. Tan, Y. Wang, Y. Fang,"Do singular values contain adequate information for face recognition", *Pattern Recognition* 36 (3) (2003) 649–655.

[19] J. Ye,"Generalized low rank approximation of matrices", in: *Int. Confe. on Machine Learning*, pp. 2004, pp. 887–894.

[20] B. Le Roux and H. Rouanet, *Geometric Data Analysis*. New York: Sp