Random Forest Algorithm Based Strain Analysis on Composite Materials using Digital Image Processing

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Abstract - **For engineers, knowledge of strain analysis is crucial as it has a critical role in several engineering designs and practical work. Condition monitoring of various composite structures is very crucial in engineering in the wind, civil, aviation, and auto sectors. This article provides comparison study of strain analysis of jute material using conventional method, Digital image correlation, regression analysis and random forest algorithm. The result shows that mean square error obtained using random forest algorithm is $3.8*10^{-4}$ which is least in comparison to contact- basedmethod.**

Keywords: Strain analysis, Jute material, Digital image Correlation, Regression analysis, Random forest algorithm. Jutematerial,

1. INTRODUCTION

To engineers, knowledge of strain measurement is critical as it has a crucial role in many several technical designs and practical work. When systems and models are becoming more and more complex than before, an accurate measurement of strain is most important, as a wrong result could lead to a disastrous accident and could also result in loss of lives [1]. Condition monitoring of various composite structures is very crucial in wind, civil, aviation sectors. Nevertheless, by taking into consideration, the geometry and scale of the systems, it can become difficult to evaluate critical points. Conventional methods such as strain gages are frequently used to quantify elongation, but these conventional methods cannot provide full-field data but only display the measurement data at a few distinct locations [2].

And the contact points of tool create unwanted stress concentration to the specimens, and conventional methods are also dependent on external environmental factors like humidity, temperature [3]. Also, their expenses and complexity create improper measurements. To improvise the conventional techniques of the strain measurement method, as Digital Image Processing had been introduced. Digital Image correlation is used to find the strain distribution,

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The outcome obtained in the above method is found is compared with the two-machine learning algorithm.

Geosynthetics are plastic based polymeric materials and employed in a range of geotechnical application. One amongst those innovations is that the introduction of geosynthetics into the sector of engineering science. The use of geosynthetics is, still novel within the civil industry. Continuous strain response throughout testing of geosynthetics provides reasonable and clear understanding of the specimen characteristics. The exact cause of the deformation zone is crucial and becomes very necessary with in the presence of seams in a geosynthetics. Such variable strain zones are unknown in traditional mechanical strain determination systems, may identify the reasons in the field and incorrect strain determination, and may either result in unconservative layout design or potential catastrophic failures. New developments in building industry growth are aimed at bringing geomaterial design and installation works into practice. They will greatly decrease resource consumption as the lifespan is up to120 years, and they also have several unique properties such as: high strength and lower levels of deformability, resistance to water spills; bio-stability; ultraviolet resistivity, and also resistance to alkaline and acidic spills; temperature tolerance and longevity [15].

2. LITERATURESURVEY

CvBlob library and open CV was applied to find blobs. Connected region in the binary image is named as blobs. After detecting connecting region area of the each blob in pixel square were extracted, then background is then subtracted to find the centroid [3].

VLSI CSD filter model for object signal pre-processing. Where the decimation filter for CSD coefficients was developed, a new serial bit and parallel systolic bit VLSI architecture for CSD coefficient filter was introduced next. VHDL synthesis simulations were performed for CSD filters, and the result showed that implemented system requires little space for VLSI [4]. The captured images were then processed using a C++ block matching technique. The algorithm was then complied with the LABVIEW language of graphic programming and incorporated into a user- friendly algorithm called BAMD. Because of their reasonable hardware requirement and fastimplementation

block-based matching techniques they are mostly applied in recognizing the pattern problems [5]. BAMD uses the minimum absolute difference, which in particle tracking is known to be most reliable search techniques and has been shown below.

$$MAD(d1, d2) = \sum mod(P(X_k, Y_k) - P(X_{k+1} + d1, Y_{k+1} + d2))$$

$(d1^\cup, d2^\cup) = \arg minimum\ MAD(d1, d2) (2)$

Where d1^u,d2^u = Horizontal and vertical displacement, respectively.

A new active technique called ViBeExt was introduced to improve the accuracy and dependence of the high-speed background subtraction process Visual Background Extractor (ViBe) at very limited additional cost. The primary concept behind ViBe is the mean neighborhood filter used to establish the spatial association of pixels. For more accurate updating of the context model, the ViBe is implemented with edge characteristic info. [6] And it has been proven that ViBeExt provides more accurate detection of moving object in complex scene. Background subtraction is important process in many video content analysis extracting foreground object from video sequences is a crucial step in image processing. Improved version of ViBe and multiple filtered technique in the field of image processing were proposed to increase the accurate analysis of video crack detection [7]. This method involves two main steps: 1. ViBe algorithm is used to find the moving crack in video, 2. A suitable threshold is used to classify all pixels in binary image in to two groups background and foreground. And uses filter area and change the area if less than a specific number to back; filtering can be used to eliminate the residualnoise.

A two-dimensional deformation measurement algorithm was developed to calculate the deformation in the loaded structural component using digital image correlation method [8]. This compares the displacement of the random speckle's patterns of original and deformed image. Finding the deformation is either Real Time or Non-Real time. Different techniques are used here, Digital Image Correlation is used for continuous tracking of marks or Artificial Intelligence can be used to search image that is compatible with the library of acceptable marks. While testing only the pixel in the immediate vicinity of marks are processed. The gauge length between two marks is monitored and updated and strain should be calculated. The strain measurement algorithm is developed using MATLAB program which can be analyzed using MATLAB image processing toolbox [9]. Image matching technique used in DIC is iterative method. The iterative methods are always lengthy. DIC works by comparing a part or test piece's digital photographs at various stages of deformation. The system is capable of measuring the displacement of the surface by tracking pixel blocks and build up full field vector fields of 2D and 3D deformation maps. The pixel blocks must be random and special with a variety of contrast and intensity levels [10] for DIC to work effectively.

3. EXPERIMENTALSETUP

The experimental setup is as shown in Fig1. It consists of a camera mounted on the stand used to capture the continuous image of specimen, light source to uniformly light the specimen, specimen under load with mark on its surface, and a computer for programming. Digital image comparison provides a complete field deformation calculation that compares mathematically two images taken in two separate states, one before strain was induced and the other after inducing the deformation. The images obtained are processed in digital format and the measuring algorithm is used to locate the displacement and therefore the strain for the image processing.
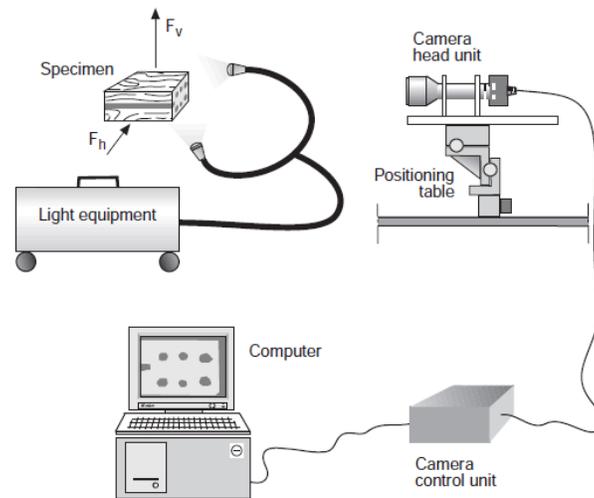
Fig. 1: Schematic of experimental set up [2].

Fig. 2: Experimental set up.

It is necessary to acquire image sequences of rapidly moving objects with high temporal resolution for many applications in machine vision and scientific research. Normal camera process 25 frames/sec , but high speed solid-state camera offers 100 to 15,000 frames per second.

For specimen marking water-based paint or printer ink is preferred because these remain more flexible under load and are less likely to flake. Only thin layer of paint is be applied because thick paint is more likely to flake, and it can affect the surface of the specimen. Solvent based paints are not used because it might affect the specimen properties. Recommended materials for marking are: water based printer color, stamp ink or computer printer ink, non-permanent marker pens, laser printer toner powder.

An array of pulsed high-intensity LEDs illuminates the sample. The pulsing increases ambient light rejection. There will be a polarizing filter in front of the long wavelength LEDs so that the light emitted is all in the same direction. The lens is fitted with two filters. The camera polarizing filter is set at right angles to the lighting array polarizing filter to remove saturation effect of shiny surfaces. The camera band pass filter center should be same as that of wavelength of LED's in order that all the other lights of different wavelength will be rejected, thus ambient light cannot affect the test area. Camera length can be changed to get different Field of View to give different range of specimenextensions.

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- Sprinkled pattern on the surface of the specimen.
- Recording un-deformed and deformed sample of digitalimages.
- Use DIC technology to achieve complete field displacement and strain.

4. RESULTS ANDDISCUSSIONS

The polymer material Jute is tested for tensile property, material testing lab. Jute material is subjected to different load as shown in Fig.3, and strain and stress is tabulated by using conventional method as shown in table 1. The plot ofstrain Vs stress is shown in Fig4.In this, the specimen is subjected to tensile loading and images of specimen is taken at an interval of every 2 sec, the images are taken until the specimen breaks under the tensile loading, the captured images are stored and DIC is implemented using NCORE tool and readings are compared with data obtained from the conventional method. The simulated result is as shown inFig5.

Fig 3. Specimen testing of Jute material

Table 1: Jute material tensile testing data using conventional method

Key Word		Product Name	
Test File Name	1.xtak	Method File Name	Polymer tensile.xmak
Report Date	4/29/2019	Test Date	4/29/2019
Test Mode	Single	Test Type	Tensile
Speed	5mm/min	Shape	Plate
No of Batches	1	Qty/Batch	1

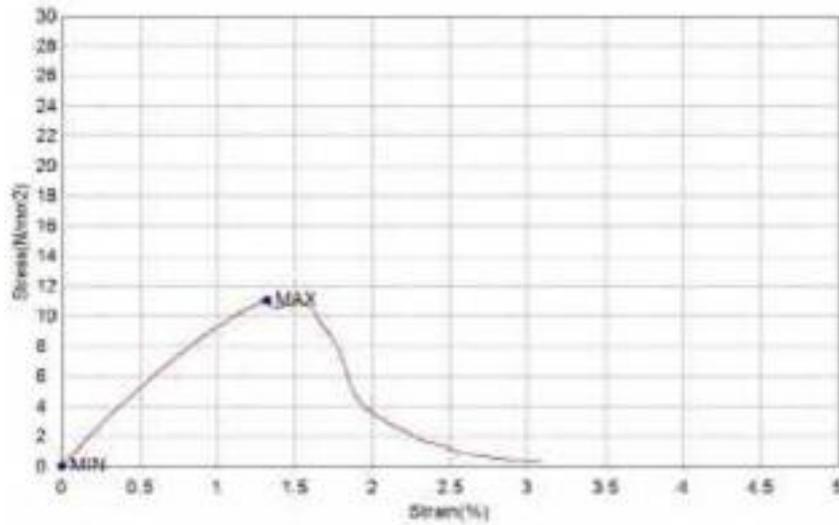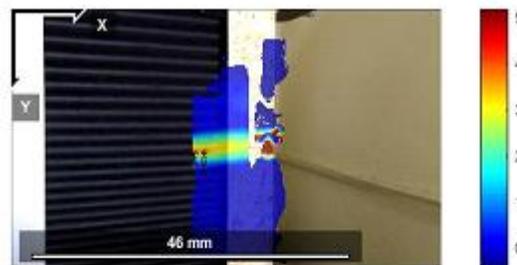| Name	Max_Force Calc. at Entire Areas	Max_Stress Calc. at Entire Areas	Max_Strain Calc. at Entire Areas	Break_Force Sensitivity: 10
Parameters Unit	N	N/mm2	%	N
1 , 1	1006.64	11.0619	1.31682	-.-
Average	1006.64	11.0619	1.31682	-.-
Standard Deviation	-.-	-.-	-.-	-.-
Range	0.00000	0.00000	0.00000	-.-

Figure 4. Stress- strain graph of jute material.

Type: eyy-plot

Reference Name: 1.png

Current Name: 31.png

Analysis type: regular

RG-DIC Radius: 100 | Strain Radius: 15 | Subset Spacing: 5

Diffnorm Cutoff: 1e-06 | Iteration Cutoff: 50 | Threads: 2

Step Analysis: Enabled | Type: Seed Propagation

RG-DIC Subset Truncation: Enabled | Strain Subset Truncation: Enabled

Image Correspondences: [0 1]

Units/pixels: 0.03252 mm/pixels

Correlation Coefficient Cutoff: 0.5772

Radial Lens Distortion Coefficient: 0

Max: 8.9002 | Median: -0.0950 | Min: -0.4311

Fig 5: DIC simulated output

 Regression analysis is a predictive modeling technique that explores the relationship between the dependent (target) and the independent (predictor) variable (s). This technique is used to forecast, model time series and find the relationship between the variables causal effect. The relationship between force and strain will be established. Linear Regression: It is one of the most common techniques of modeling. The dependent variable is continuous in this method, independent variable(s) may be continuous or discrete, and the form of the line of regression is linear. Linear Regression uses the best fit straight line to establish a relationship between dependent variable (Y) and one or more independent variables (X). It is defined by a $Y = a + b*X + e$ formula, where a is intercept, b is line slope, and e is error term. Based on the given predictor variable(s), this formula can be used to predict the target variable A regression equation is an equation of polynomial regression if the independent variable's power exceeds 1. The equation below is a polynomial equation: $y = a + b*x^2$. The best fit line is not a straight line in this

regression technique. It's a curve that blends in with the points of information. The linear and Polynomial regression model is plotted as shown in Fig.6.
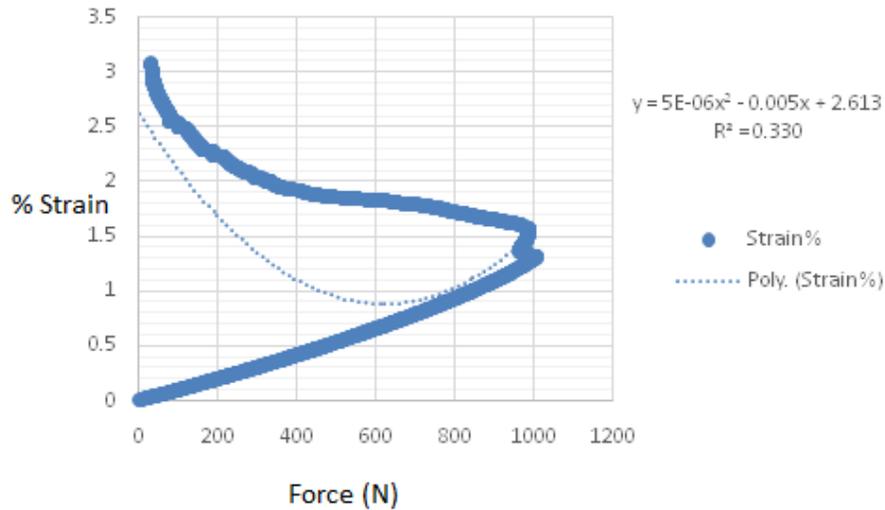

Fig 6: Force-strain curve using Linear and polynomial regression coefficient 0.330 (Normal Range is 0 to 1). Max % strain= 1.3 (which match with the conventional method)

Random forest is a popular supervised learning algorithm, comprising of decision trees. "Ensemble" means a cluster of "weak data" is required and combined to form a reliable predictor. The random forest method is frequently referred to as the "improved version" of the decision tree-based system, because now several trees are used to accurately provide prediction values based on the data set provided as the input. Due to simplicity of calibration and ease of the analyzing process, the method quickly became popular. Unlike the classical algorithms for building decision trees, the training set contains only a pre-determined number of random selected signs which are used in the random forest technique when building each tree, at the stages of splitting the vertices, and a full tree is constructed that is, each tree leaf contains observations of only one class. A random forest model is developed with the bin size of 50, and the correlation coefficient is obtained in the specified range between +1 to-1.
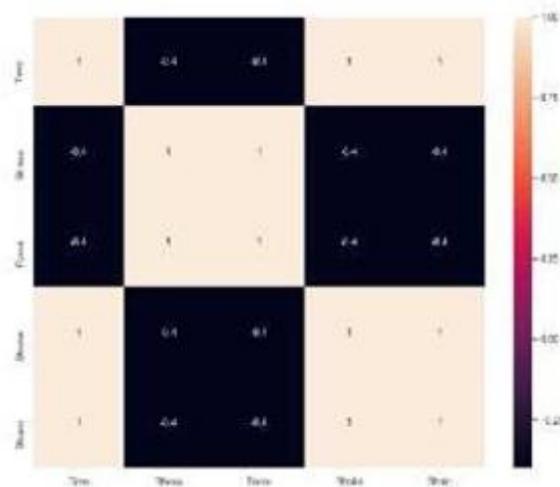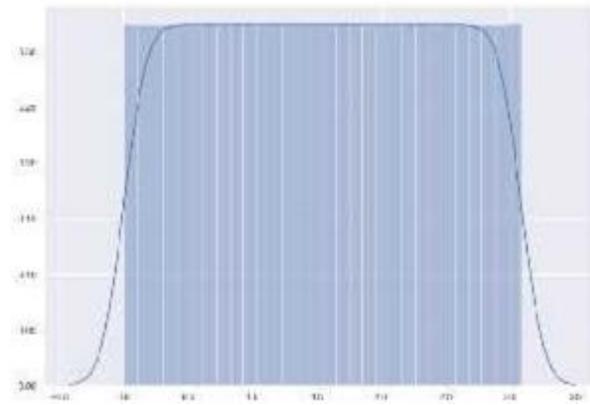

Fig 7: Correlation coefficient matrix

Fig 8: Scaled plot of avg % strain of samples with bin size=50

CONCLUSION

The primary objective of the work was to identify critical faults in the mechanical structures in order to eliminate the failures that may occur over a period. The existing literature provides several approaches have been used over composite structures and the results have been satisfactory in identifying the strain of a material at during the breakdown point. In this work random forest algorithm-based approach has been investigated on composite structures using digital image processing. The comparison with the conventional method proves that the proposed method provides better reliability.

REFERENCES

[1] Khoo Sze Wei,Saravanan Karuppannanan, "Development of an optical strain measurement method using Digital Image Correlation," in AJSR.411-422,2013

[2] Per-Erik Austrell,BertilEnquist,AndersHeyden "contact free strain measurement using MATLAB image processing toolbocx"RG,pp.123-135.

[3] Abhijit Verma,SachinAgarval,SiddarthSrivatsa,"strain measurement using image processing" IJRT 2278- 0183,Vol2, Issue2,Febrauary2013

[4] Yoon Gi Yang, Nam Ik Cho and Sang UK Lee "Design and VLSI implementation of CSD filter for preprocessing of imagesignals"ICECS'96

[5] .Aydilek,M.ASCE, Murat Guler and Tuncer B Edil,M.ASCE " Use of image analysis in determination of Strain distribution During Geosynthetic Tensile testing" ASCE0087-3801(2004)18:1(65).

[6] Fang Zhu,Ping Jiang, Zhaobin Wang "ViBeExt :the extension of the universal background subtraction algorithm for distributed smart camera" 978-1-4673- 2467-0/12

[7] Ahmed Mahgoub Ahmed Talab,ZhangcanHuang,FangXi,LiuHaming"Moving Crack Detection based on Improved VIBE and Multiple Filtering inImage Processing Techniques" Ijsip2015.8.2.27.

[8] Bing Pan,AnandAsundi,HuiminXie,JianxinGao,"Digital image correlation using iterative least squares and pointwise least squares for displacementfield and strain field measurement" Elsevier Optical and Lase engineering 47,209;865- 874.2009.

[9] B. Pan ,K. Qian, H.Xie, "Two dimensional Digital Image correlation for in plane displacement and strain measurement, a review", Measure Sci Tech 20- 6(2009),1-17.

[10] Van Thoung Nguyen, SeongJin Kwon, Oh Heon Kwon, "Mechanical Properties identification of sheet metals by 2D digital image correlation method, Elsevier, Science Directs, Procedia Engineering 184(2017)381-389.