Implementation of Embedded Predictive Analysis System: Prevention of Bridge Wreckage

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ABSTRACT: In the modern era of twenty first century, bridge wreckage has become a burning issue thereby focussing the attention on vulnerability of countless human lives and structural damage in the states of human infrastructure. This paper aims to envisage the probability of bridge collapse using an AI neural network using photo-elastic stress measurement data as inputs from photo-elastic sensors.

KEYWORDS: Artificial Neural Network, Birefringence, Photo elasticity, Polariscope Residual stress.

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1. INTRODUCTION

Photo elasticity is one of the classical optical methods for measuring residual stress. [1]. One of the oldest known methods of determining residual stress field magnitudes in a material that is transparent to visible light is by the method of photo elastic imaginarywhich was first proposed by D Brewster [2]. E.G. Cooker and L.N.G Felon from the University of London formalised the idea [3] which later became the standard text in this regard and introduced the Polariscope to the world of Material Science and Solid Mechanics which have since been used to determine complex stress distributions. This process is a direct consequence of the phenomenon of stress induced birefringence [4] where the refractive index of the material is dependent on the polarisation direction of light. The Calcite crystal is a popular example of an anisotropic birefringence crystal which even in its pure homogeneous form bends lights of different polarisation in different ways. However, Stress Induced Birefringence is a resultant of the various internal forces in the sample producing distinct layers of stress distributions of a constant magnitude conventionally called isochrones.

Now with the advent of Digital Polariscopes [5] and improved image recording and data accusation and processing, the stress curves will show us material response to various impacts and impulses, impossible to have been ever recorded by pure mechanical response of structure on macroscopic levels. Thus, this has opened up an entirely new way of studying bulk material. One such software resource package frequently used in stress analysis is Photo Stress [6], however here for limitation of availability of the same algorithms of stress analysis have been incorporated in MATLAB [7] with a python bridge for final analysis.

Thus with these age old methods of experimentation we wanted to develop an embedded device that can help in prediction of wreckage and possible collapse of civic structures and as a case study we would took up one of the most recurring problems of today's ever developing cities that is the case of collapse of Overhead pedestrian and transportation bridges (colloquially known as fly-overs) which during a collapse cause heavy casualties and economic losses, especially in today's crowded cities where the bridge is so much in use that thorough inspection and audit is perhaps not possible in a high frequency. The most alarming incidents of bridge wreckage are 'The Tacoma Narrows Bridge collapse', 'Hintze Ribeiro Bridge collapse', 'Mississippi River bridge wreckage', 'A pedestrian bridge in China collapse', 'Martha bridge of South Kolkata collapse' etc.

Till date most stress response analysis is done with the help of seismic methods, mostly after major earthquakes to prevent structural ageing and deterioration [8]. Here the introduction of Optical Birefringence data for stress analysis brings in more accurate and organized approach in this regard as the localisation of the data is concrete and unique to the specific area under study, thus the learning curve of the neural network would not be affected by sensor data overflow and a curve as suggested by Emily K Winn in her paper[9] can be aptly set-up using images of the birefringence isochrones over a period of time and can be fed into multiple layers of the network for a deep learning approach to the situation consisting entirely of localised stress data.

2. METHODOLOGY

A polystyrene sheet of 2mm thickness, a polariscope, a digital camera with spatial resolution of 768*576 pixels and with 256 gravy levels per colour, a

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processing unit, a load frame, large memory storage for continuous recording of input data and a chassis for holding the complete experimental setup and most importantly a strong network connection to processing units are needed to build the target embedded system. The polariscope contains a polarized light source and analyser .The analyser is another polaroid screen placed at an angle of highest contrast with the linearly polarized light source, in front of the lens of the camera unit, which sends the images to the processing board for statistical analysis by feeding the image data as pixel intensity array of isochromatic pattern, residual stresses[10] is fed as an input to the proposed neural network running on MATLAB software[11] in the processing board, which produces a graded prediction of the severity of damage in the area after receiving many such data inputs from various sensor units placed along the structure and displaying the output on the on-site unit and forwarding the same whenever necessary.

For testing our hypothesis, a controlled lab was set up and the neural network was trained in a way that mimics the case-study scenario, the camera connected to the processing unit running the algorithm was placed behind the analyser polaroid. A polystyrene was placed for image feed in front of a linearly polarized source and a load unit (with data feed to the processing board) is switched on that gradually increases the load and thereby applying a shearing stress on the polystyrene sheet.Each time the polystyrene sheet tears, data is labelled and fed into the network as weights/bias. The cost function is therefore computed every instant by giving higher weightage to the differentially graded drain of network biases.

The neural network is two layered with twenty-five connections on each layer; out of which the last layer of five nodes indicate the severity of breakage. If the output turns to be zero, then the condition is treated alright. But if the output turns out five, then the condition indicates severe breakage. We used five loads for experimental purposes but for more accurate results higher levels of load of varying breakage can be used. Images which are taken for testing are cross validated with random classifiers with both regular and non-regular breakage data. The training is stopped when accuracy reaches up to eighty five percent. In this way, the training data is tested and thereby deployed in real time scenario. After the training by back-probing and cross validation is done, testing is carried out by keeping an unknown load on acrylic sheet and thereby incrementing the load with unknown amount gradually until the acrylic sheet breaks. Thus, output is generated at every instant which indicates probabilistic severity of breakage. Therefore, use of photo-elasticity is done in measuring the status of a bridge and an algorithm is executed which by use of historic pre-modelled data of stress conditions during various collapses would effectively predict if the present case scenario has a high probability of collapse or not by recording continuous images of the isochrones in the polariscope and feeding it into the neural network.

3. RESULTS AND DISCUSSION

After the completion of experiment, snaps of polystyrene sheet with increasing stress is taken. The pictures are as follows:

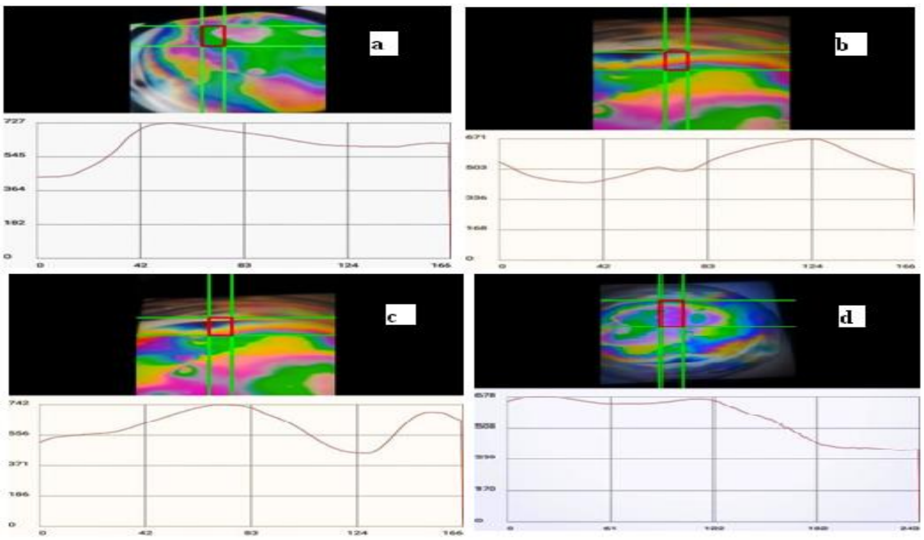

Figure 1 Spectrum observed in a specific region of a polystyrene sheet under different residual stress conditions is plotted with residual stress (in MPa) vs distance from the centre (mm).

Here in MATLAB every graph is plotted between the stress level and the distance from surface which will give us the idea about the stress level. So that we can do the statistical analysis on it. In Fig 1.a with the increase of residual stress intensity peak attains maxima close to originand then it starts decreasing and then after certain limit the graph attains saturation. In Fig 1.b the graph attains maxima far away from origin. Fig 1.c it shows dual maxima. In Fig 1.d, first the plot is more or less constant in nature and after a certain limit

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it decreases. It is observed that Fig 1.a &1.c and Fig1.b&1.d shows opposite characteristics. So, we infer that the spectrum changes with change in residual stress and from this data probabilistic severity of damage is therefore analysed. So, for the photo-elastic stress analysis, the neural network is to be fed with RGB (Red, Green, Blue) colour code data values in the MATLAB[11]. The desired colour to be printed or to get an output, the colour code is to be given to the system, while the system will analyse the given picture and will give the percentage of the colour. Using MATLAB [12] algorithm, we have given this data to the input layer of Artificial Neural Network [13]. Here ANN gives us the output data within 1 to 5 to specify different conditions of the bridge material.1 signifies that the material is absolutely okay, 2 to 4 denotes the severity of bridge wreckage and 5 denotes complete bridge failure. Thus, by virtue of an Artificial neural Network the whole predictive analysis process is done perfectly. ANN works with the help of following diagram and Formulas: -

$Z=x_1*w_1+x_2*w_2+x_3*w_3+\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots+a_n*n_a b*1$

$Y^{\wedge}=a_{bout}=\text{sigmoid}(z)$

Where, sigmoid (z) =1/ (1+e^{-z}) [14]

Propagation function[11] calculates the input of a particular artificial neuron j which is received as output from its predecessor neuron i.

$$p_j(t) = \sum_i o_i(t) w_{ij}$$

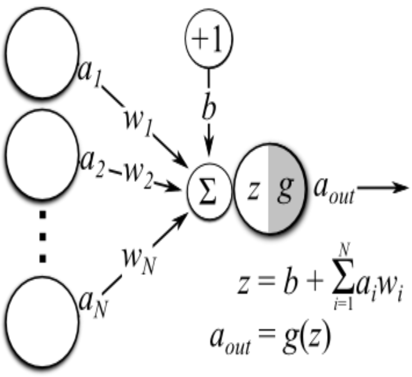

Figure 2 Operation at one of the neurons of a neural network [14]

Here w=weight (that brings the importance of input),b=bias (it has an extra input to neuron and has its own connection weight),x_1, x_2, andare the input values of a signal. When a signal arrives, it gets multiplied with weights. Weighting is the analysis of a particular aspect in comparison with other aspects in a given data. In ANN[14], the weight is generally the aspect which determines the signal strength at a connection.Thus, after feeding the whole data to ANN, we get the following results: -

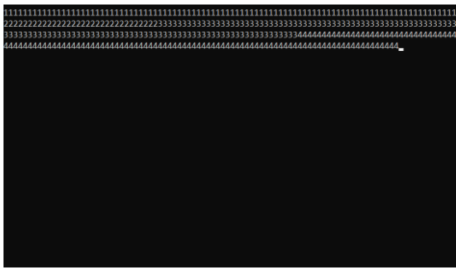

Fig 3.a Deployment of testing set data

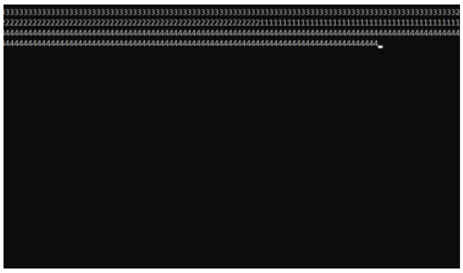

Fig 3.b Deployment of training set data

This way we have done our test of predictive stress analysis on a polystyrene sheets.This is the process we want to implement in our case study of Bridge wreckage. In a newly developed bridge we can incorporate our proposed model to predict the condition of bridge. Every time it will give us the residual stress data of different portions of bridge. Doing RGB analysis of spectrum and plotting graph, artificial neural network [13] will report us the condition of that as a probabilistic data. Thus, without taking regular maintenance we can anticipate a probable collapse and hence abet the same in a short period of time.

4. CONCLUSION

The photoelastic analysis of residual stresses in glass results in isochromatic fringes, which are sometimes called test fringes that effectively reveals the presence of residual stresses. Photoelasticity [15] is non-destructive method of stress analysis that utilizes a polariscope in synchronization with optical system that consists of two dimensional signal process along with non- contact visualization. The residual stress analysis with polariscope provides accurate results which are more reliable as compared to the data received from seismic vibrations. The cost of entire experimental set up is reduced thereby making it more economical for use. Moreover since residual stress analysis by the principles of photo-elasticity [16] does not involve any moving parts therefore this method is much more efficient to indicate the severity of bridge collapse.Most importantly since the system can be placed at different locations therefore severity of damage can be treated with immediate effect.

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