

ARTIFICIAL NEURAL NETWORKS APPLICATION IN THERMOGRAPHY

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ABSTRACT

In this paper, we present an application of artificial neural network (ANN) analysis in the thermovision identification of the studied thermal fields. Precise thermal field identification plays an important role in distinguished technological processes, for instance in metallurgy. Our efforts were focused in this direction. Thermovision outputs are usually thermograms with a form of a quasi-coloured imaging record of an observed temperature field. A thermogram is usually registered and presented in a form of an electronic or printed image. The character of such a document is informational only, and real temperature values are difficult to detect. The exploitation of neural networks is advantageous, if it is necessary to express complex mutual relations among sensor-based data. More accurate results of the predictions of different metallurgical parameters with the exploitation of neural networks are based on the fact that the application of neural networks enables the assignment of relations among process parameters which cannot be traced using common methods due to their mutual interactions, the considerable amount of data, dynamics and the thus ensuing time demands.

INTRODUCTION

The thermovision technique has often been used in technical practice as a physical process for the optimization of some technological processes. Thermovision outputs are thermograms that are in the form of a quasi-coloured imaging record of a temperature field on an observed surface. The temperature of each detector element is transformed and digitalized. Correct temperature detection from detector acquired data is entirely dependent on many factors, for instance emissivity [1].

The paper [2] introduces a new method to improve the reliability and confidence level of defect depth measurement based on pulsed thermographic inspection by addressing the over-fitting problem.

In [3], the authors measure heat fluxes on the rotating components of gas turbines. In this work, quantitative image processing tools were developed to perform fast and accurate infrared thermography measurements on 3D-shaped film-heaters directly deposited on the turbine endwalls. The newly developed image processing method and instrumentation were

used to measure the heat load on the rotor endwalls of an axial turbine.

The fatigue behavior of the AZ31B magnesium alloy subjected to three-point-bending tests was studied in [4]. The real-time recording of the surface-temperature-evolution data of specimens was obtained using the infrared thermography technology during fatigue. The characteristics of heat production and transfer were described and the correlation between temperature and stress distribution was analyzed.

A key aspect in assessing the thermal standard of building envelopes is the quantification of the heat loss through thermal bridging, which can be expressed in terms of the linear thermal transmittance [5]. This study shows how the infrared thermography technique can be used as a non-invasive and easy-to-use method to provide quantitative measures of the actual thermal bridging performance. The novelty of this approach includes the evaluation of the actual heat flow rate caused by the thermal bridge.

Crossulacean acid metabolism is an alternative carbon fixation pathway that imparts high water-use efficiency in plants adapted to warm, semiarid climates. To facilitate this research, new tools which simplify procedures for detecting and measuring CAM are needed [6].

An original approach based on active Infrared Thermography addresses the very challenging issue of the non-destructive analysis of bonded, repaired laminates. [7] Difficulties come from the weak property contrast between parts of repaired assemblies and the thickness of the joint. Strong attention is given here to the control of experimental test conditions (heat load, boundary conditions), which enable developing a physically consistent numerical model of the thermal problem.

The most recent literary and original experimental results collected from different research and practical areas are presented in [8]. It is shown that the modern infrared technique acts as an indispensable laser partner in various biomedical and many other applications and technologies. And vice versa, the laser-based methods and techniques often serve as an appropriate research instrument enriching infrared technique measurement data with independently obtained information.

In our work, we present ANN as a tool for the analysis of thermograms. The presented method also enables carrying out

other mathematical analyses that can provide required information about the thermal field and its influence on the quality of technological processes.

EXPERIMENTAL REALIZATION

A thermogram is usually only available in electronic form, like a picture in a computer memory, or a printed one. In this case, we have an effective qualitative overview about a hot surface temperature field, on the other hand it is not possible to have a more precise value of the measured temperature.

Geometric bonds of a temperature field with the actual measured object are clearly visible in the picture, however more precise temperature detection is a problem. Various mathematical methods of picture analysis might be used for this reason. One possible method for the transformation of thermogram colour to temperatures seems to be an application of artificial neural networks (ANN).

Each thermogram pixel is characteristic in its colour that corresponds to the temperature in this pixel. Colour is preferably expressed by the brightness of three fundamental colour components, known under the R, G and B definition. Thermovision software consists of some algorithm that binds the measured temperature with a specific RGB brightness. This algorithm differs as well as the number and diversity of exploited colours with various camera types. That is the reason why the same thermograms of the same object measured by various cameras differ. It is necessary to find the type and function parameters:

$$T = f(R, G, B) \quad (1)$$

A specific function is usually not known, so it seems to be useful to replace a real function with a mathematical description represented by ANN. Learning of a neural network is carried out based on data acquired from the color scale that accompanies thermograms. An example of such a scale is in Fig.1. From Fig.1, it is apparent that each temperature from a minimal to a maximal value, the values of which are part of the scale, is uniquely assigned by a unique color. The temperature scale from minimum to maximum is linear. It is easy to create software that allows a random spot inside the scale to be assigned a temperature and color components of the RGB picture.



Figure 1 Colour thermogram scale used for learning, validation and testing of an artificial neural network

Now, based on data acquisition, it is possible to learn an artificial neural network uniquely and with sufficient accuracy to assign a corresponding temperature to each R, G and B colour combination. A three-layer neural network has been used with teacher learning, and with a Back propagation learning algorithm. Application of the software “Statistica - Neural Networks“ has been used for neural network creation [9], [10], [11]. Topology 3-5-1 (see Fig.2) has been used for its

simplicity, that exhibited a similar accuracy as other ANN with more complicated topology.

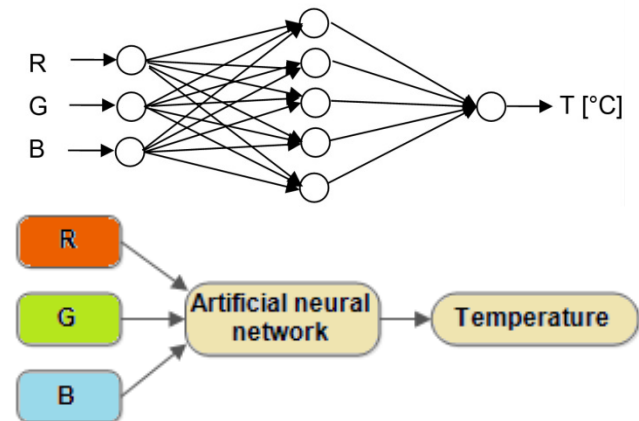


Figure 2 Used topology of the artificial neural network

For thermogram backward analysis, a computer program has been created, the design of which is visible in Fig.3

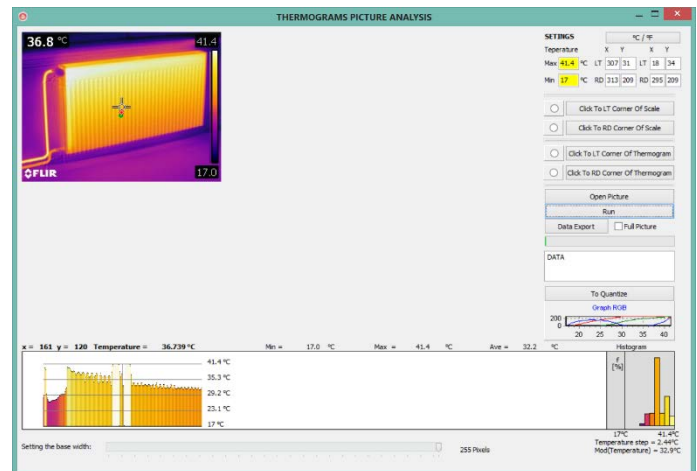


Figure 3 Design of software for thermogram backward analysis

The interaction with the program is simple and intuitive. First, the operator downloads a thermogram picture into the program. This operation is started by pressing the “Open Picture” button. A thermogram picture appears on the screen. The colour temperature scale must be part of the picture, including the minimum and maximum temperatures visible on the scale. In this phase, it is necessary to write the minimum and maximum temperature values into editable program inputs, which are marked by yellow. Then, the left upper-hand corner of the color scale is entered; the option is chosen by the “Click To LT Corner Of Scale” button, followed by a mouse click on the selected pixel. The thus selected operation is by its execution indicated by the highlighting of the graphic pixel before the “Choose” button.

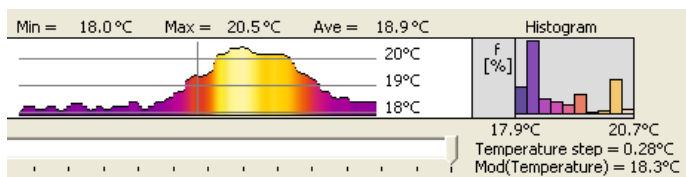


Figure 4 Temperature graph image in a horizontal line with the corresponding histogram

Similarly, the right lower-hand corner is selected “Click To RD Corner Of Scale”. The way the location of the scale in the thermogram picture was marked, must also be marked by means of the “Click To LT Corner Of Thermogram” and “Click To RD Corner Of Thermogram” buttons in the left upper-hand and right lower-hand lower corners in the chosen thermogram working area. By pressing the “RUN” button, the backward temperature to the RGB values algorithm is initiated for all pixels along the colour scale. The program marks the minimal and maximal temperatures in the selected thermogram area and is ready for its own thermogram analysis. By moving a mouse cursor over a selected thermogram area, coordinate values and its temperature are continually shown. At the same time, a temperature graph in the horizontal line and length, which can be set by the ScrollBar component under the graph, is being shown. Next to the graph, a percentage distribution temperature histogram in ten temperature lines is allocated. The histogram extracts from data of the same horizontal line. Next to the temperature at the selected spot, the minimal, maximal and average temperature in the above mentioned horizontal line is displayed (see Fig. 4). An interesting view provides the data export to Excel, where the 3D temperature field graph of the square area can be displayed. The size of the square area is determined by the component “ScrollBar” setting. The export starts after pressing the “Data Export” button, and clicking the mouse in the imaginary square area in the thermogram. The image of the exported thermogram part into a 3D graph in Excel can be seen in Fig.5.

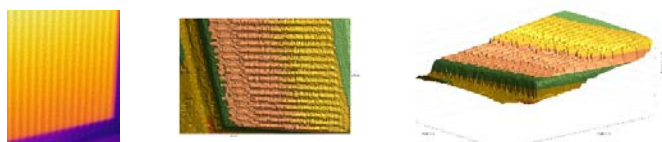


Figure 5 The result of a selected thermogram part export to Excel

It is easy to supply the thermogram analysis program with other useful statistical computing and reproduction based on user demands. An example might be a graphical shape of a quantum thermogram that is a graph analogy with isolines. Such a projection can be obtained by pressing the button “To Quantize”. The result of a thermogram quantum of a heated material can be seen in Figure 6.

CONCLUSION

The thermogram analysis program enables the backward temperature field detection of the followed object based only on a thermogram picture supplemented by a color scale. The picture must be in a bitmap format, and might also be carried

out of a printed form by means of a scanner. Taking a photo by camera or with a mobile phone may not guarantee the correct colour interpretation. The program is accompanied by a number of visual and statistic elements in the form of numbers and graphs. These features can further be enhanced. Besides thermograms, other technical pictures, in which any information is symbolized by a colour, may also be analyzed. An example can be meteorological and other maps and pictures, where mechanical tensions are marked in color, liquid convection and so on. The preciseness of the used method is sufficient with respect to the correctness of the temperature field measurement of the monitored objects.

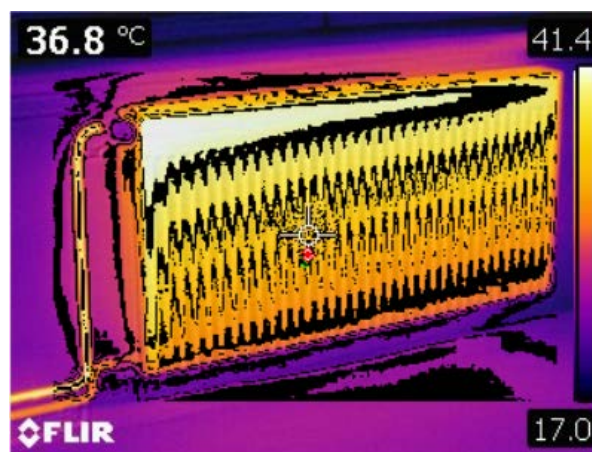


Figure 6 The result of a thermogram quantum of a heated material

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