

ARTIFICIAL INTELLIGENCE ELEMENT EXPLOITATION FOR THERMOGRAM ANALYSIS

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Abstract

Thermovision technique has been more often used in a technical practice as a technological processes control and optimization tool. Thermovision outputs are thermograms that in a form of quasi-coloured imaging record temperature field of an observed surface. Thermograms find their usage not only in metallurgy, but also in electrotechnology, engineering, construction industry and other sectors. Thermograms are often retained and presented in a form of an electronical image, or are printed. The character of such a document is informational only, and real temperature values are hardly reproducible. Artificial intelligence components and image computer analysis can be exploited for thermogram temperature field information reconstruction, or other mathematical analyses can be carried out based on such acquired data optionally that can provide required information about the quality of a technological process. Thus the aim of the paper is to create the program for the analysis of thermograms, which allows detection of temperature field monitored object only from the picture supplemented by colour scale.

Keywords: Artificial intelligence, metallurgy, thermovision, measurement of temperature, image recognition

1. INTRODUCTION

Such technologies and devices keep exploiting in technological practice that allow information acquiring about surfaces temperature of observed objects. This has been caused by consistent development of thermovision technique at constantly dropping prices of sufficiently high-grade and available equipment. Thermogram data is the result of a surface object temperature that can be further processed by means of special programs, being part of provided metering technique. 2D image of an observed object surface temperature field is usually the graphical output where individual temperatures are encoded into a scale of various pseudo-colours. Such arisen image is together with colour scale, to which temperatures are assigned, stored as a data image file appropriate for electronic publication, or is submitted as a printed copy. This image has generally high predicative ability, but due to a low resolution of individual colour shades, human senses are not able backwardly with sufficient accuracy to identify a temperature of a selected spot. Need of a backward analysis of real temperatures from thermograms might often occur, so a real possibility of an image analysis and artificial intelligence elements (or different approaches respectively) for computer program creation might be used. Next to the temperature assignment to a random pixel in a thermogram, the program could contain other useful features that would alleviate the temperature field analysis of an observed object. This article deals with a creation of such a program.

2. FUNDAMENTALS THERMOGRAM CREATION

The principle of a thermovision camera operation is generally known. Followed object is scanned like any other image through an objective which transmits only such thermal waves that belong to a thermal radiation of the

followed object. On principle, the intensity of a heat flow from radiated object is measured, not directly a temperature. Radiation temperature activity on a thermovision camera detector produces a temperature change of a specific element in the detector matrix. Temperature of each detector element is transformed and digitalized. Consequently, a temperature field is generated that corresponds to the temperature field of the followed object surface. Correct temperature detection from detector acquired data is entirely dependent on many factors. The most well-known parameter is the surface emissivity of measured object; minor could not be also radiation reflections from other objects and environment conditions, in which the radiation spreads. In this article will be assumed that temperature detection is precise enough for given purposes. Common thermovision cameras use detectors with 320x240 pixel resolution, better ones 640x480 pixel. Some technical application use first-rate thermovision cameras with even higher detector resolution. Such acquired data is possible to process with the software accompanied the thermovision camera. Visualization of an object temperature field is called a thermogram, where temperatures in single points of an image are expressed by a specific colour [1]. To be able to estimate these colours, thermogram is accompanied by colour scale, supplemented with a temperature scale. Data from thermovision camera could be processed in any way, and provide the operator with temperature values in selected spots, or process statistical data of selected area respectively. It is usually possible to acquire maximal, minimal and average temperature.

The situation is different in case there is at disposal a thermogram in electronic form only, like a picture in a computer memory, or a printed one. Only pictorial information is at disposal in such a situation that on one hand gives an effective qualitative overview about surface object temperature field, on the other hand it is not possible by mere eyesight to backwardly assign a measured temperature with a sufficient accuracy. Like an example may be given a thermogram shown in **Figure 1**. All thermogram pictures in this article were provided by Department of Materials Forming, VŠB - Technical University of Ostrava, Faculty of Metallurgy and Materials Engineering.

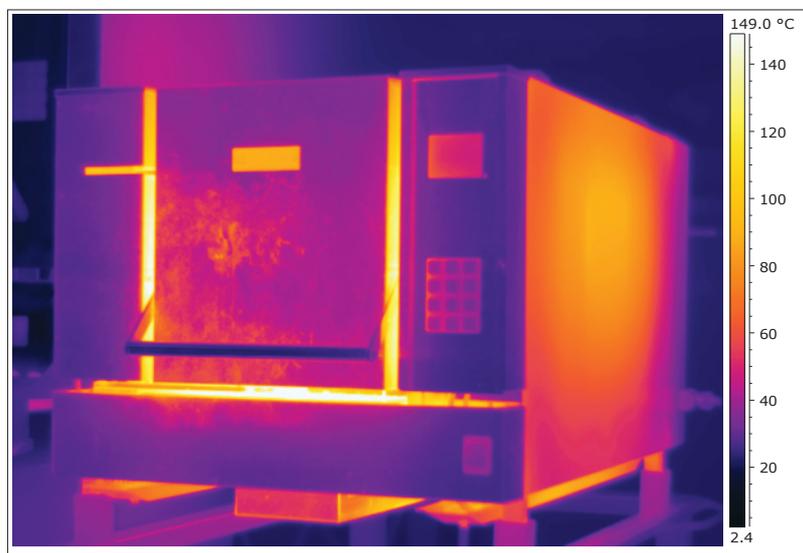


Figure 1 Thermogram example of an electric furnace surface, made by thermovision camera FLIRT

3. NEURAL NETWORK EXPLOITATION FOR THERMOGRAM PRIMARY DATA RECONSTRUCTION

Colour outputs of quality thermograms contain sufficient information about measured temperature field of observed objects surface. They provide a human eye with useful, but only preliminary global data about a temperature field. Geometric bonds of a temperature field with own measured object are clearly visible on the picture, however backward temperature detection is problematic. Many times it is advisable to analyse pictorial thermograms deeper, which however anticipates to acquire a real temperature field backwardly, and which

was originally acquired by thermovision technique. Various mathematical methods of picture analysis might be used for this reason. One possibility of a backward thermograms colour transformation 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 R, G and B definition. Thermovision software consists of some algorithm that binds measured temperature with a specific RGB brightness. This algorithm differs as well as the number and diversity of exploited colours at 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 type and function parameters:

$$T = f(R, G, B) \tag{1}$$

A specific function is usually not known anything about, so it seems to be useful to replace a real function with mathematical description represented an artificial neural network. Learning of a neural network is carried out based on data acquired from colour scale that accompanies thermograms. An example of such a scale is on **Figure 2**. From **Figure 2** is apparent that each temperature from minimal to maximal value, the values of which are part of the scale, is uniquely assigned a unique colour. Temperature scale from minimum to maximum is linear. It is easy then to create software that allows a random spot inside the scale to be assigned a temperature and colour components of RGB picture.



Figure 2 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 assign a correspond temperature to each R,G and B colour combination. Three-layer neural network has been used with teacher learning, and with Back propagation learning algorithm. Application “Statistica - Neural Networks“ has been used for neural network creation [2]. Results were some useful topologies and approaches. Topology 3-5-1 (see **Figure 3**) has been used for its simplicity that exhibited similar accuracy as other ANN with more complicated topology.

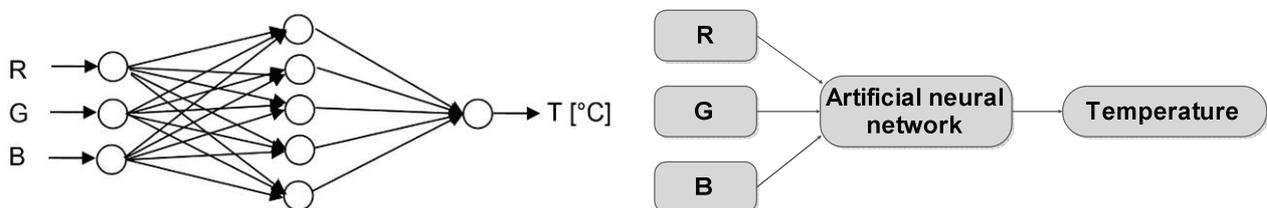


Figure 3 Used topology of artificial neural network (Source: own)

4. THERMOGRAM ANALYSIS SOFTWARE

For thermogram backward analysis, a computer program has been created, the design of which is visible on **Figure 4**.

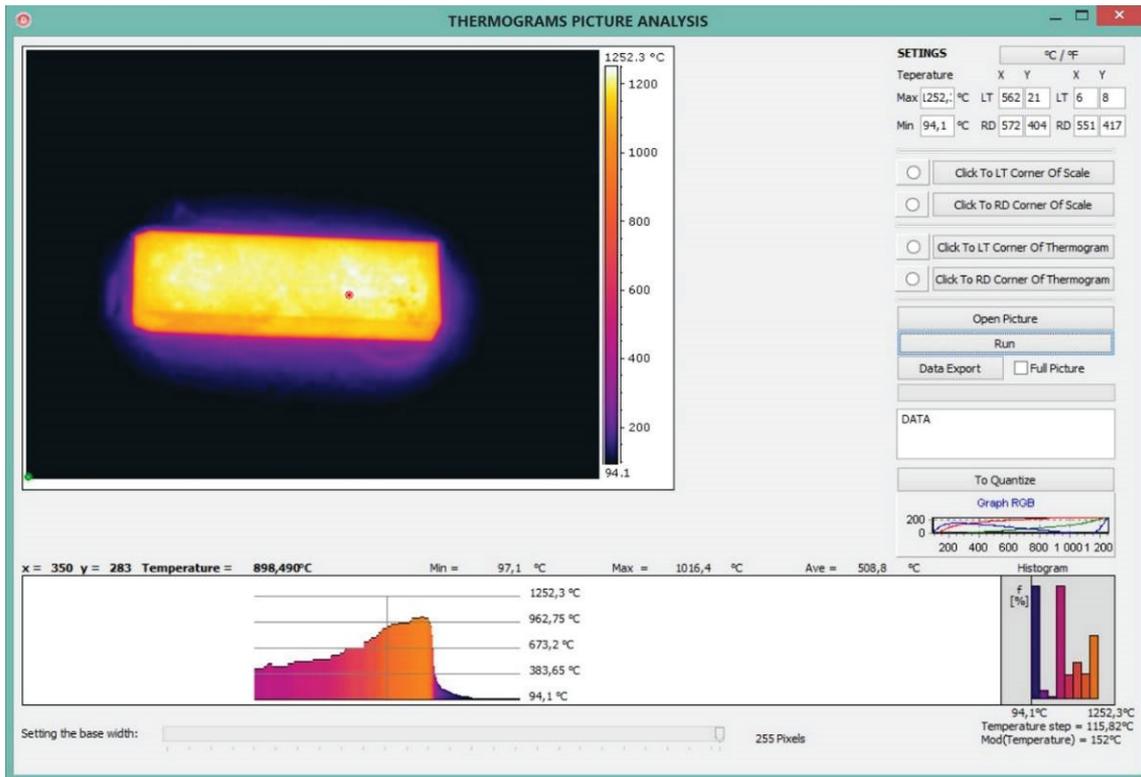


Figure 4 Design of software for thermogram backward analysis

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 “Open Picture” button. Thermogram picture appears on the screen. Colour temperature scale must be part of the picture, including minimum and maximum temperatures visible on the scale. In this phase it is necessary to write minimum and maximum temperature values into editable program inputs, which are marked in yellow. Then, left-hand upper corner of colour scale is entered; the option is chosen by “Click To LT Corner Of Scale” button, followed by a mouse click at the selected pixel. Thus selected operation is by its execution indicated by highlighting of graphic pixel before “Choose” button.

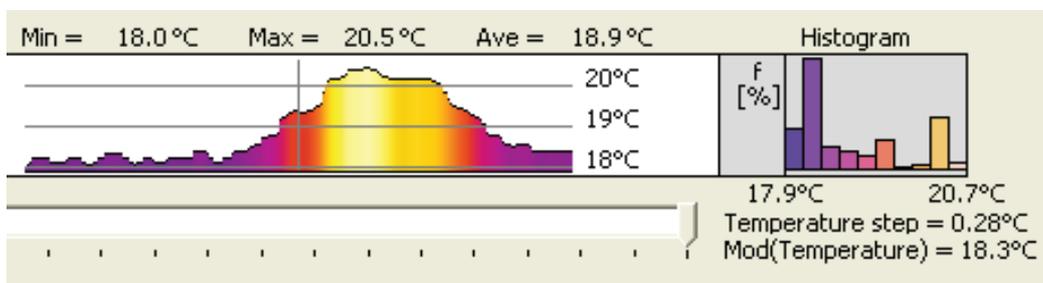


Figure 5 Temperature graph image in horizontal line with corresponding histogram

Similarly, right-hand lower corner is selected “Click To RD Corner Of Scale”. The way the location of the scale in thermogram picture was marked, must also by means of “Click To LT Corner Of Thermogram” and “Click To RD Corner Of Thermogram” buttons left-hand upper and right-hand lower corners in chosen thermogram working area be marked. By pressing “RUN” button, backward temperature to RGB values algorithm is initiated for all pixels along the colour scale. The program marks 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 horizontal line and length, which can be set by 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, minimal, maximal and average temperature in the above mentioned horizontal line is displayed (see **Figure 5**). An interesting view provides the data export to Excel, where 3D temperature field graph of square area can be displayed. The size of square area is determined by component “ScrollBar” setting. The export starts after “Data Export” button pressing, and mouse clicking into an imaginary square area in the thermogram. The image of exported thermogram part into 3D graph in Excel can be seen in **Figure 6**.

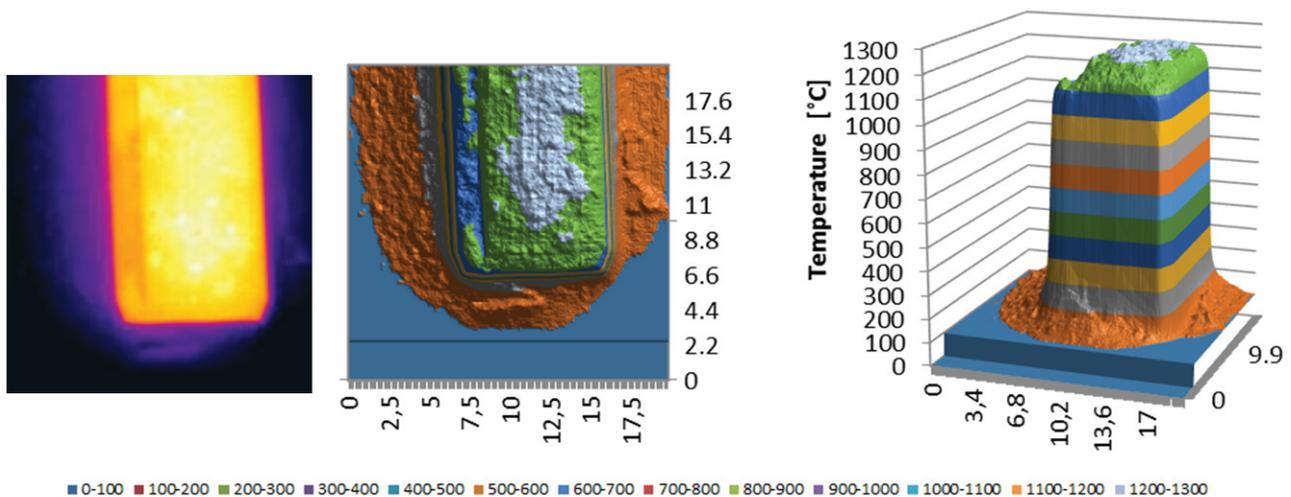


Figure 6 The result of a selected thermogram part export to Excel

It is easy to supply the thermogram analysis program with other useful statistical computings, and reproduction based on users' demands. The example might be a graphical shape of a quantum thermogram that is a graph analogy with isolines. Such 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 7**.

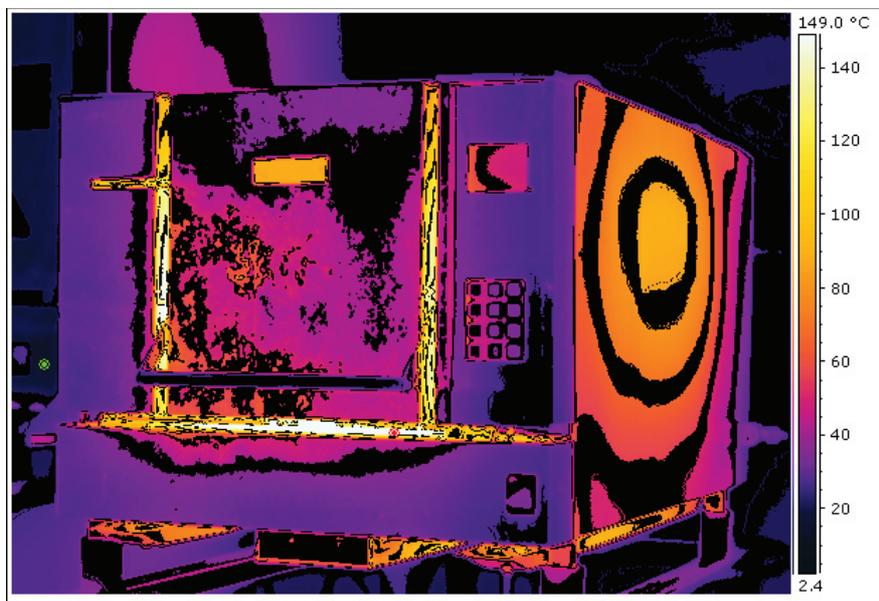


Figure 7 The result of a thermogram quantum of a heated material

5. CONCLUSION

Thermogram analysis program enables backward temperature field detection of the followed object based only on thermogram picture supplemented by colour 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 does not have to guarantee the correct colour interpretation. Program is accompanied by a number of visual and statistic elements in the form of numbers and graphs. These features can further be enhanced. Next to thermograms, also other technical pictures, in which any information is symbolized by a colour, might be analysed. An example can be meteorological and other maps, pictures, where mechanical tensions are marked in colour, liquid convection and so on [3], [4], [5] [6]. The preciseness of used method is sufficient with respect to the correctness of temperature field measurement of followed objects with thermovision technique.

ACKNOWLEDGEMENTS

The work was created in the Projects No. SP 2016/107 and SP 2016/86.

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