BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi" din Iaşi
Volumul 62 (66), Numărul 2, 2016
Secţia
CONSTRUCŢII. ARHITECTURĂ

USING THERMOGRAPHY AND ARTIFICIAL NEURAL NETWORKS IN CIVIL ENGINEERING

BY

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Received: June 12, 2016
Accepted for publication: July 27, 2016

Abstract. By applying the thermography and neural networks, a diagnosis of the heat loss can establish, followed by the state of a building. The infrared images recorded by the camera, obtained through the thermography, will be the input data for the artificial neural network. For this type of problem, a feed-forward, multilayer, supervised neural network is adopted and trained with a back-propagation algorithm. The activation function used in this matter is a function specific to the information classification problems, namely the step function.

Keywords: diagnosis; heat loss; back-propagation algorithm; surface; temperature.

1. Introduction

Thermal methods involve a temperature variation analysis of building elements used to detect degradations and faults of the building elements, material particularity irregularities, detecting thermal bridges etc.

In civil engineering, thermography is considered an effective technique for non-destructive tests, without contact on the structure and is used to assess the performance of the building envelope. Any civil building can be evaluated in a very short time and the aim of this evaluation is to check if there are any

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discontinuities in the insulation. Also, the assessment by thermography involves measuring the effects as a result of carrying out repairs or rehabilitation of the envelope.

Thermographic images are recorded by special infrared cameras and then transferred to a computer to be subjected to image processing. The images represent those areas proposed for deficiencies control regarding material properties and are presented in the form of temperature variation, by different colors.

The colors found in the images from thermography are: violet, blue, green, orange, red, yellow and white. Dark colors, such as purple, blue, green colors are specific to low temperatures and the rest of the light colors, such as orange, red, yellow and white correspond to high temperatures.

The effect of the material discontinuity subjected to heat flow control is shown in figure 1. When the heat flow is directed from inside to outside, „hot spots" are created on the image and when the heat flux is directed from outside to inside ,,cold spots,, are created on the image.

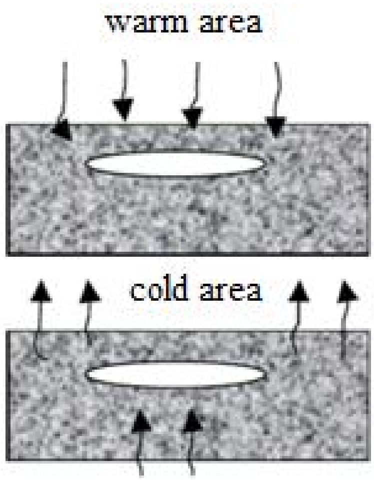

Fig. 1 – The effect of heat flow interruption (Carino, 1994).

The thermography method indicates only the areas where there are irregularities or heat loss, the depth cannot be determined. It should be considered that the results achieved are influenced to some extent by temperature and humidity.

Specific thermal anomalies for reinforced concrete structures occur in case of a porous and segregated concrete, in case of inadequate performance of the construction work, in case of air infiltration in the joints or in the presence of moisture etc.

Specific thermal anomalies, in case of masonry structures, occur due to degradation of the thermal insulation, masonry disruption, inhomogeneity of the masonry walls, condensation on the surfaces of building structural elements, etc.

A thermographic image showing a uniform temperature variation on the analysed surface accentuates the lack of insulation. A diffuse and variegated image with relatively small temperature variations in the structure indicates the presence of humidity. Images with high temperature variations, shapes and irregular edges appear in case of air infiltration.

2. Identify Areas of Heat Loss Using Thermography

By applying the thermography, it can establish a diagnosis of the heat loss, followed by the state building. Higher heat losses occur through the least isolated areas of the envelope, through the thermal bridges at lintels level, at the columns, floors, beams and reinforced concrete belts, on facades, patio areas, base of construction, roofs, etc.

It is considered as a case study a building structure with reinforced concrete frames and infill masonry. Thermography of the building is made and significant temperature variations on a level with socket, door and window gaps are detected, also, in the joints between slabs and beams, in the belt, in the column etc.

For the study the following will be considered:

a) area A, from the base of construction, where significant differences in temperature were recorder after the thermography (Fig. 2);

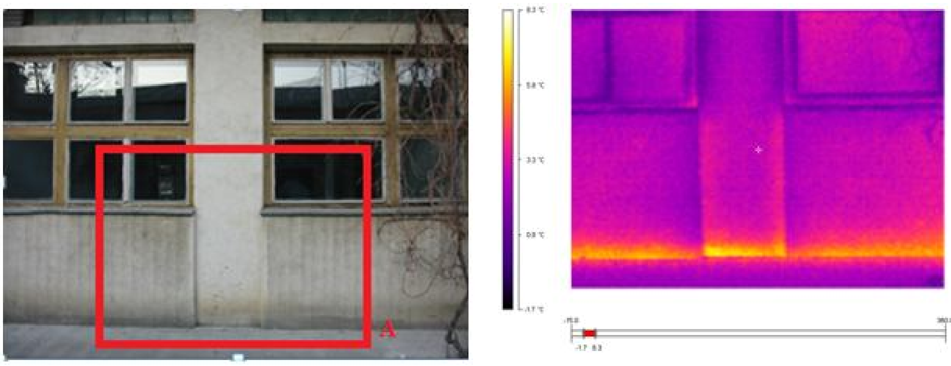

Fig. 2 – Area A, the base of construction.

b) area B, in the area of connections between structural elements of the building (Fig. 3);

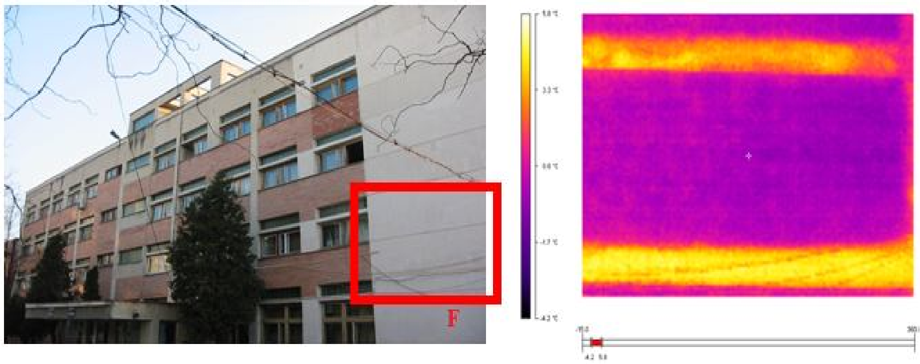

Fig. 3 – Area B, concrete beams.

c) area C, from the opening window (Fig. 4);

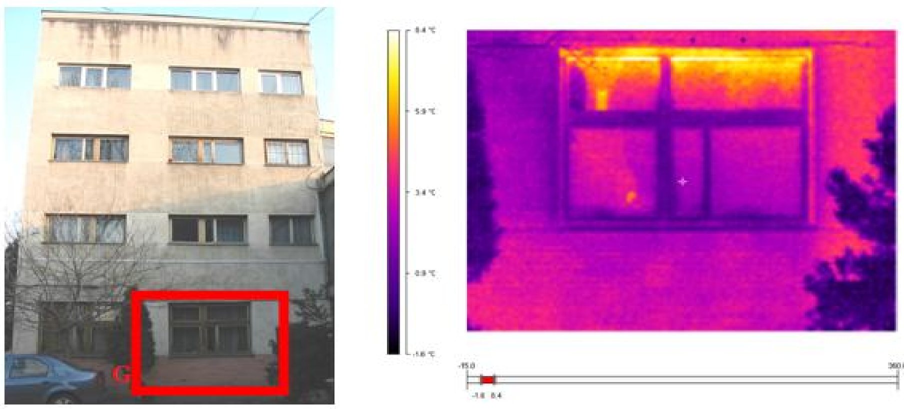

Fig. 4 – Area C, the opening window.

3. Determining the Surfaces of Heat Losses by Using ANN

The infrared images recorded by the camera by thermography will be the input data for the artificial neural network (ANN). For this type of problem a feed-forward, multi-layered, supervised neural network is adopted, the neural network being trained with back-propagation algorithm. The activation function used is a specific function information classification problems, namely with step function (Fig. 5).

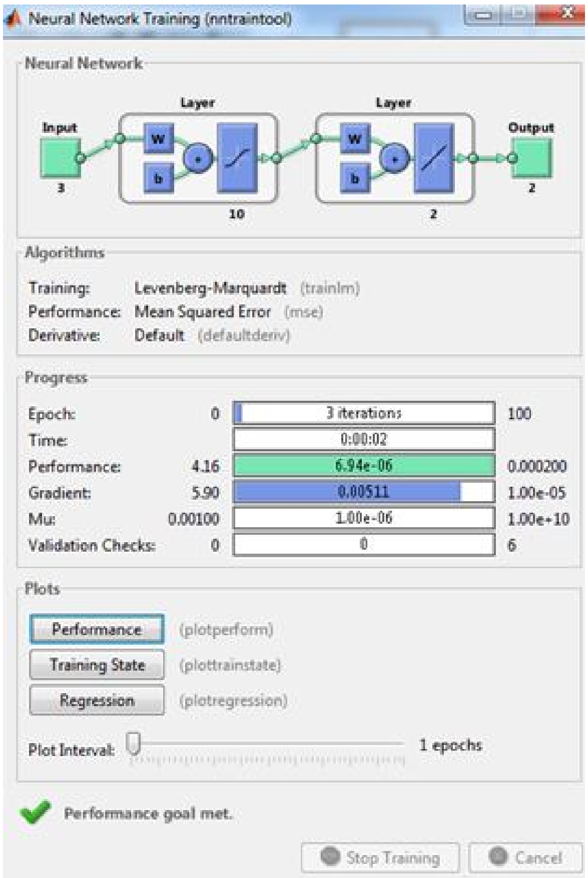

Fig. 5 – Neural network architecture.

Input data for the neural network are sets of color-sized images with small sizes so that the network training be made easier. Color samples will be selected for each region, after that, a new digital image of the ideal regions of interest is built. The output of the network consists of a matrix which is used to measure the area occupied by each region.

Each color region is associated a specific temperature, a recorded value of the unit used in the thermography process. In terms of the number of neurons and epochs used, it differs from case to case. More tests with different numbers of neuron or epochs are made until it is observed that the error is very small, less than 0.1.

The neural network is trained with the 3 areas (Figs. 6,...,8) and the results generated by the network will be presented in Table 1.

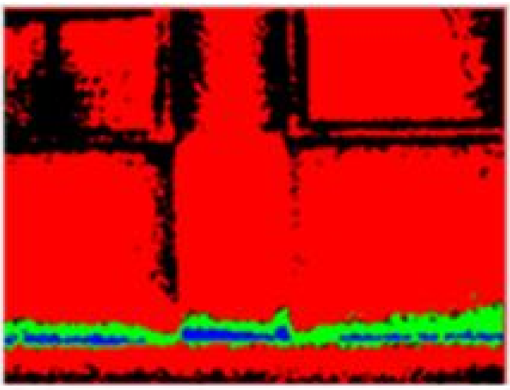

Fig. 6 – Segmented image of the area A.

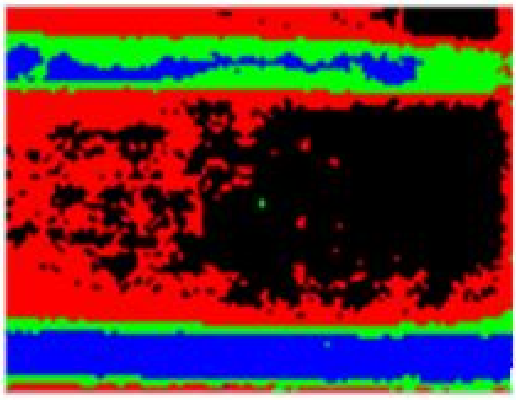

Fig. 7 – Segmented image of the area B.

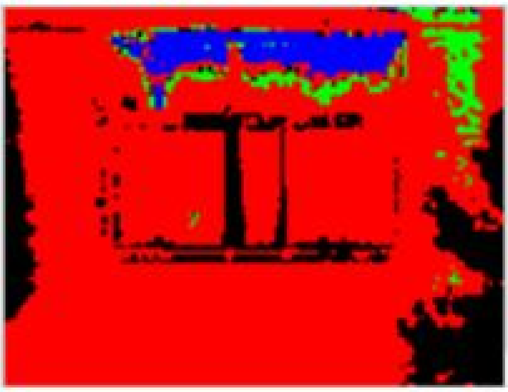

Fig. 8 – Segmented image of the area C.

T_1, T_2, T_3, T_4 represent temperatures recorded by infrared camera for each area and RT_1, RT_2, RT_3, RT_4 represent the percentages specific areas for each region where one of four temperatures are registered and by S the image area subjected to thermography. The temperature values are included in the table in ascending order, as it follows $T_1 < T_2 < T_3 < T_4$.

Table 1
Input and Output Parameters of ANN

	area A	area B	area C
Number of neurons	25	25	25
Number of epoch	100	100	100
Error value	6.936×10^{-6}	91.054×10^{-6}	157.936×10^{-6}
T_1, [°C]	0.8	–1.7	-1.6
T_2, [°C]	3.3	0.8	3.4
T_3, [°C]	5.8	3.3	5.9
T_4, [°C]	8.3	5.8	8.4
R_{T1}, [°C]	29.288	33.87	13.24
R_{T2}, [°C]	66.45	32.14	78.14
R_{T3}, [°C]	3.321	11.82	2.47
R_{T4}, [°C]	0.941	22.17	6.15
S, [cm^2]	165	550	540
Heat loss, [cm^2]	7.037	186.95	46.80

4. Conclusions

For area A, thermal losses are recorded at the base of construction. Image segmentation using artificial neural network helps with the identification of the cause of the thermal losses, in this case being the humidity and the determination of the surface with heat losses.

In case of area B, by thermography thermal losses were identified close to the concrete beams. By segmenting the image using ANN there is noted a uniform temperature variation on the analysed surface which highlights the lack of insulation. It is indicated that the surface where thermal losses were registered to be isolated with a material having a thermal conductivity different from that of the surface that does not have thermal losses.

For area C, by thermography the existence of heat losses at opening window have been observed. Following image segmentation, ANN generated images with large temperature variations, shapes and margins, thus indicating air infiltrations.

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UTILIZAREA TERMOGRAFIERII ŞI A REȚELELOR NEURONALE ARTIFICIALE ÎN CONSTRUCȚII

(Rezumat)

Prin aplicarea termografierii şi a rețelelor neuronale artificiale, se poate stabili un diagnostic al pierderilor de căldură, urmat de cel a stării clădirii. În urma termografierii, imaginile înregistrate de camera cu infraroşu vor fi date de intrare în rețeaua neuronală artificială. Pentru acest tip de problemă se adoptă o rețea neuronală feed-forward, multistrat, supervizată şi antrenată cu algoritmul back-propagation. Funcția de activare folosită este o funcție specifică problemelor de clasificare a informațiilor şi anume funcția de tip treaptă.