Assessment of internal forces from stress state by means of ANN

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Summary

ISANNIF is an image processing program (.png, .jpg, .bmp, .jpeg) using artificial neural network. The program can be used in Civil Engineering to determine the geometrical characteristics of the internal forces from a section taken as an image.

The input parameters of ANN are an image of the section with related dimensions, a chromatic map of the stresses and stresses values specific to each colour.

KEYWORDS: internal forces, neural network, stresses, chromatic map of the stresses, image processing.

1. INTRODUCTION

Most of the structural analysis programs with the finite element are designed to determine the values of stresses and specific deformations.

In the design of building structures is insufficient the knowing of tensions, so that it is necessary to integrate the stresses on the characteristic sections to obtain the efforts that are needed for the specific verifications in civil engineering. The intervention in the software part of these programs for this operation is sometimes very difficult, requiring specific programming knowledge.

A theory concerning the integration of normal or tangential stresses in a given area, which underlies these analysis programs with finite element consists in the approximation of surfaces with linear elements. This approximation leads to approximate numeric values of the internal forces in a section.

The *ISANNIF* software (*Intelligent System Artificial Neural Network Internal Forces*) was designed from the need to know the state of effort in any section of a structural element. The software is based on the processing of an image as .png, .jpg, .bmp, .jpeg, using an artificial neural network in Matlab programming language.

The program can determinate the state of efforts in any section of a structural element based on maps provided by the analysis programs with finite elements, without any kind of restriction. More, the program provides the state of internal force (moments) beside any axis imposed on a section.

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2. THE SEQUENCE OF STAGES IN THE PROGRAM ISANNIF

2.1 Artificial Neural Network

In classical theories of image recognition issues, artificial neural networks of the feedforward type through local connection have been shown to have an advantage in extracting local features and combining them to form higher order features.

The receiving field of neurons from the hidden layer (which simplifies the processing without calculation) is not the same for the input layer, but it must be at best adjacent to avoid the possibility of losing information from the input layer. It is recommended to use two-dimensional squares layers and reception fields.

The ISANNIF program uses for the image processing a feedforward type artificial neural network, with three layers, which is free of feedback and is not recurrent. ANN consists of 3 neurons in the input layer, 3 neurons in the hidden layer and one neuron in the output layer.

The architecture of the artificial neural network for the ISANNIF program is shown in figure 1.
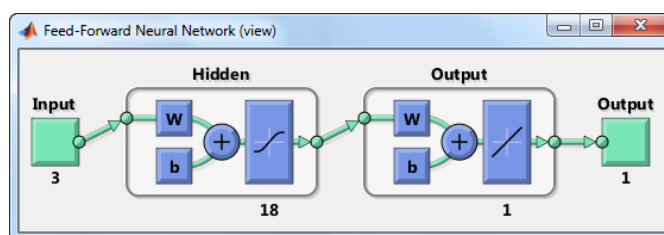

Figure 1. The architecture of neural network

Neural network input consists of an *RGB* matrix consisting of 3 lines and *n* columns M_{3xn}, where *n* is in the range [2,18] and represents the number of colours encountered on the image.

Neural network output is a matrix formed by one line and *m* columns, M_{1xm}, where *m* represents the numerical values of the internal forces associated with the colours of the matrix M_{3xn}. The numerical values number specific to tensions is one greater than the number of colours, since each colour is assigned both the maximum and the minimum values of stress level.

The activation functions used are tansigmoidal from the input layer on the hidden layer and linear from the layer hidden on the output layer.

2.2 The work steps of ISANNIF program

The graphical user interface of the program has been created with MATLAB GUIDE (*Graphical User Interface Development Environment*)*. The initialize variables* require that to each object has to be assigned *handles* that allow the manipulation of the object properties. The program ISANNIF contain:

– the object named *,,load tension image''*, an object that generates, after cutting the section from the image of the stresses, a colour matrix;

– the object named *,,load colour map''*, an object that generates, following colour selection from the colour map, a matrix of colour-specific stresses.

With the resulting matrices and section sizes, the neural network is trained. The sequence of work steps is presented in the logic scheme of figure 2.
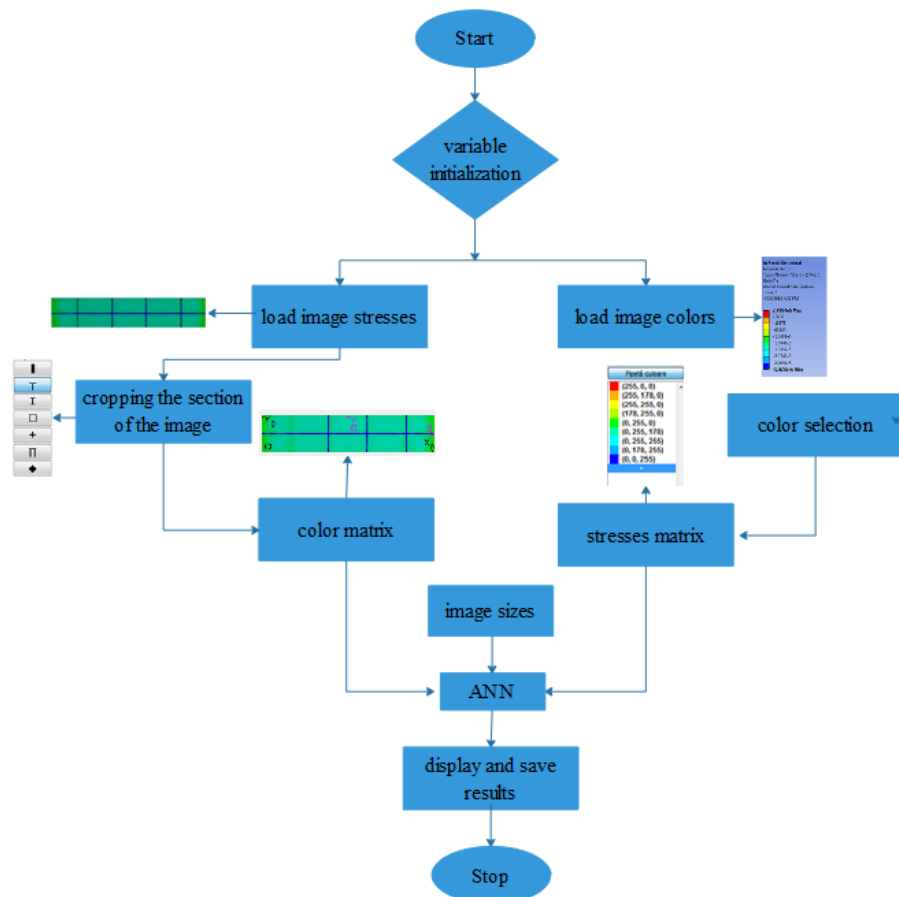

Figure 2. The logic scheme of program ISANNIF

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2.3 The calculation stage of ISANNIF program

Using the results generated by the neural network we can determine:

- the gravity centre position (X_{OG}, Y_{OG})

The coordinates of the gravity centre are calculated as the arithmetic mean of x and y coordinates specific to all pixels in the section area.

- moments of axial inertia (I_x, I_y)

Calculation formulas specific to moments of inertia for a homogeneous section are taken from the Theoretical Mechanics. They are customised within the IASNNIF program being expressed in pixels. The section area is the product of the area of a pixel expressed in meters and the number of all the pixels from which the image is formed.

Moments of inertia are calculated by:

$$I_x = \frac{b_{pixel} \times h_{pixel}^3}{12} \times k + \sum_{n=1}^{k}((x_{G_n} - x_G)^2 \times ratio(1) \times ratio(2)) \qquad (1)$$

$$I_y = \frac{h_{pixel} \times b_{pixel}^3}{12} \times k + \sum_{n=1}^{k}((y_{G_n} - y_G)^2 \times ratio(1) \times ratio(2)) \qquad (2)$$

where:

b_{pixel} = the length of pixel expressed in meters;

h_{pixel} = the height of pixel expressed in meters;

k = the number of pixels from which the section is formed;

$ratio(1)$ = the height of one pixel, in meters;

$ratio(2)$ = the length of one pixel, in meters;

X_{G_n} = the position of the gravity centre of the n pixel in the x direction, related to the XOY system;

y_{G_n} = the position of the gravity centre of the n pixel in the y direction, related to the XOY system;

x_G = the position of the gravity centre of the section, in the x direction;

y_G = the position of the gravity centre of the section, in the y direction;

the moment of centrifugal inertia (Ixy)

The moment of centrifugal inertia is calculated as the sum of the products of the four area specific terms: the differences in both directions between the position of the gravity centre of the n pixel and the section, and the pixel area expressed in meters on the x and y directions. The centrifugal moment, Ixy, can be determined with relation 3:

$$I_{xy} = \sum_{n=1}^{k}((x_{G_n} - x_G) \times (y_{G_n} - y_G) \times ratio(1) \times ratio(2)) \tag{3}$$

– the main directions (α) and the main moments of inertia (I_1, I_2)

Both the main moments of inertia and their main directions are determined in the ISANNIF program with the formulas according to the literature.

- axial force (N), shear forces (V_x, V_y) and the bending moments (M_x, M_y)

The formulas of the internal forces in a section, used in the ISANNIF program, are highlighted as:

$$N = \sum_{i=1}^{k} \sigma_{medie\ norm,i}^{k} \times ratio(1) \times ratio(2) \tag{4}$$

$$M_x = \sum_{n=1}^{k} (y_{G_n} - y_G) \times \sigma_{medie\ norm,i}^{k} \times ratio(1) \times ratio(2) \tag{5}$$

$$M_y = \sum_{n=1}^{k} (x_{G_n} - x_G) \times \sigma_{medie\ norm,i}^{k} \times ratio(1) \times ratio(2) \tag{6}$$

$$V_x = \sum_{i=1}^{k} \sigma_{medie\ tang,i}^{k} \times ratio(1) \times ratio(2) \tag{7}$$

$$V_y = \sum_{i=1}^{k} \sigma_{medie\ tang,i}^{k} \times ratio(1) \times ratio(2) \tag{8}$$

where:

$\sigma_{medie\ norm,i}^{k}$ = the mean normal tension specific to k pixel;

$\sigma_{medie\ tang,i}^{k}$ = the mean tangential tension specific to k pixel;

the bending moments on a particular system (M'_x, M'_y)

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In order to calculate the bending moments on a particular system, we need the position of the axes system $X'O'Y'$ in relation to the axes system X_OOY_O and the rotation of the system $X'O'Y'$. The formulas are expressed with:

$$M'_x = \sum_{n=1}^{k} y' \times \sigma_{medie\ norm,i}^{k} \times ratio(1) \times ratio(2) \qquad (9)$$

$$M'_y = \sum_{n=1}^{k} x' \times \sigma_{medie\ norm,i}^{k} \times ratio(1) \times ratio(2) \qquad (10)$$

The distances x' and y' are calculated using the relations:

$$y' = x\,cos\beta - y\,sin\beta \qquad (11)$$

$$x' = x\,\sin\beta - y\,\cos\beta \qquad (12)$$

where:

  x = the position of the particular system in relation to the axes system X_OOY_O on x direction;

  y = the position of the particular system in relation to the axes system X_OOY_O on y direction;

  β = the angle of inclination of the particular axes system;

  x' = the distance in the x-direction, calculated from the origin of the particular system to the centre of the i pixel;

  y' = the distance in the y-direction, calculated from the origin of the particular system to the centre of the i pixel;

The program trains the artificial neural network with numerical values of normal stresses generating numerical values of the geometric characteristics (position of the gravity centre, moments of inertia, the moment of centrifugal inertia, main moments of inertia and main directions) and the internal forces from a certain section (axial force and the bending moments).

It is important to note that the particular calculus axes system can only be used after the neural network has generated the geometric characteristics.

Figure 3 shows the result after the first stage of training with the map of normal stresses for a T section.

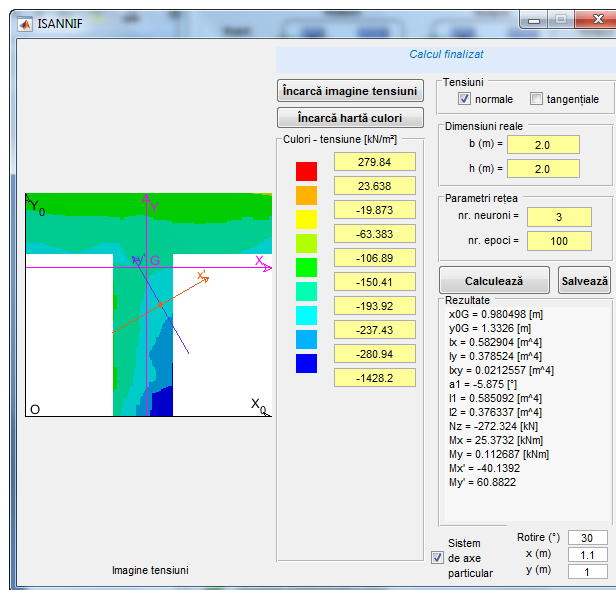*Assessment of Internal Forces from Stress State by Means of ANN*

Figure 3. The results of the ISANNIF program for the first phase with the map of normal stresses

The training of the artificial neural network with numerical values of tangential stresses generates as results the shear force on the cross section. Figure 4 shows the calculation of the shear force for the T section presented above.
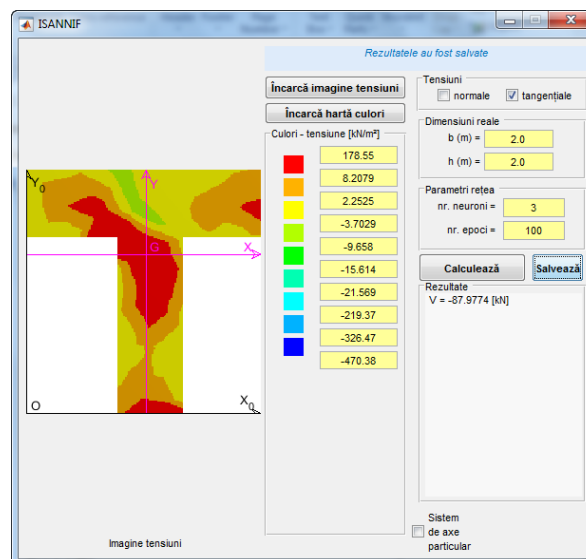

Figure 4. The results of the ISANNIF program for the second phase with the map of tangential stresses

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3. CONCLUSIONS

In the design of building structures is insufficient the knowing of stresses, so that it is necessary to integrate the stresses on the characteristic sections to obtain the internal forces that are needed for the specific verifications in civil engineering.

The ISANNIF program offers the possibility to determine the internal forces (axial force, shear force, bending moment) in any section of any form, from a structural element based on the stress maps provided by the finite element analysis programs, with no restriction. The program allows the determination of bending moments in relation to an axes system positioned at any point of the section.

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