



DATA FILTRATION ORIGINAL ALGORITHM FOR THE COMPUTER BASED CALCULUS OF THE STRESSES WITHIN AN ANALYTICAL MODEL

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Abstract: Computer based studies in engineering usually use three types of investigation methods: analytical, numerical and experimental studies. Complex phenomena may be modelled using these sources of information together with a strategy to integrate the studies in a unique overview level of understanding. These computer based studies offer a large amount of data which must be interpreted by the analyst. A method to have a quick vision regarding the data is to use diagrams, graphs and generally, visual information. In this context, automatic calculus in structural studies based on analytic models uses various methods to define the domain and to perform the according calculi. The authors have an extensive experience regarding the original computer aided analytical models. In this way, the calculus domain in cross sectional related problems was modelled by defining a Boolean algebra whose addition and subtracting math operations use some 'simple' geometrical shapes. The definition of these subdomains takes into account several aspects. An important aspect regards the points where the maximum stresses might be found inside these 'simple' shape bodies. In this way, the points inside a 'simple' shape which is a part of a domain, may offer the location of the maximum stresses inside the entire cross section. All the points inside these 'simple' shapes, which are used to define the cross section, are included in a large collection of points at the entire cross-section level. In a computer graphical representation of the stresses, for any point inside the cross section may be assigned a color related to the scale of the overall stresses. However, beside this visual method to provide information about the state of stresses, there must be also considered general criteria to locate the extreme stresses. The purpose of our study is to find the most intelligent criteria to select the smallest subset of points from the large collection of points belonging to the 'simple' shapes included in the entire cross section. In this way the first stage was to conceive a set of criteria to generate the minimum number of points in each type of 'simple' shape, taking into account the regions where the maximum values may be found for both normal and shear stresses. The second stage was to conceive a set of analytical criteria for the filtration of the large collection of points. These criteria must take into consideration the

regions where the maximum normal and shear stresses may be found in an inhomogeneous cross section and also the constraints of the algorithm. One of the most important consequences of this algorithm is the automatic analytical calculus of the extreme stresses in a generally defined inhomogeneous cross section.

Key words: data filtration original algorithm, extreme stresses locations, inhomogeneous cross section, constraints.

1. INTRODUCTION

Computer based models in engineering offer huge amount of data to be interpreted by the mechanical engineering analysts. Synthetic conclusions must be based on the thorough examination of various aspects and on the output data resulted from analytic, numeric and experimental studies. From this standpoint, elaborating intelligent conclusions using a very large amount of data may be considered similar to the attempt to drink water directly from a fire hose nozzle. In order to draw technical common sense conclusions, we must process the large amount of data using intelligent criteria which may be translated from the experts' intelligent reasoning into analytic conditions to be verified or in advanced algorithms based on such analytic conditions. Remarking the wide range of calculus instruments nowadays, we can conclude that the degree of expertise in a field may be also revealed by the capacity of a given expert to analyze the problems and to create software instruments based solutions of topmost generality. Therefore, data filtration is an important aspect, relevant in various types of studies: experimental mechanics, computer based analytic and numeric studies. Moreover, data filtration criteria are very important in conceiving hybrid models, where the high degree of integration of the 'low level' studies is paramount.

2. EXAMPLES OF DATA FILTRATION IN CONCEIVING OF THE SOFTWARE INSTRUMENTS

Experimental mechanics studies offer a large amount of data to the structural analyst, data which must have statistical relevancy. A first stage in the experimental data reduction is to conceive the criteria to reject the aberrant data. The following figure presents a representation of the 'number of samples per engine cycle', data provided by a strain gage technology experiment, [1], and the automatic drawing of the isostatics starting from the isoclines resulted by the use of an original data processors dedicated to the experiments based on photoelasticimetry, [2]. To conclude, automatic experimental data processing uses filtration condition in order to offer relevant information regarding the phenomenon under investigation.

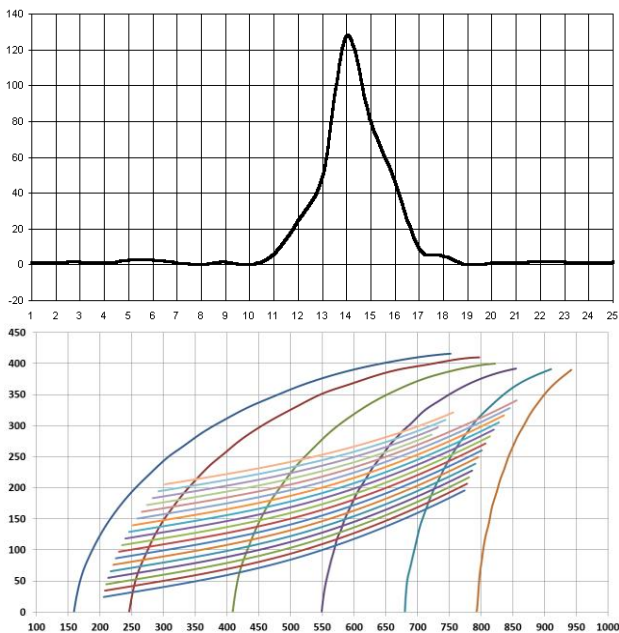


Fig. 1. Examples of data filtration in experimental studies

Another type of studies which uses data filtration is the automatic data generation for the numerical models, [3, 4], and the graphical representation of the output data resulted from finite element models, [5, 6]. There are projects based on the finite element modelling which either require various variants of the input data, or they have a high repeatability. The optimal solution in these cases is to develop dedicated software instruments to be used for both input and output data processing. Our solution regarding the output data representation employs a commercial CAD application which is linked to our software. In order to have a general interface between our software instrument used to solve the finite element model and the graphical representation module, i.e. the commercial CAD application, the data are expressed in a neutral format which can be used by a wide range of CAD applications. Moreover, the data to

be represented are filtered from the huge amount of output data resulted from the FEM original application. In this way we are able to use the facilities of the CAD software, using a small and relevant amount of data. The following figure presents some finite element models, which were created and graphically represented by the use of some original software applications. The first model presents a plate which has two simply supported sides, for the other two being used some elastic built-in supports represented in the model as two beams. The second model presents the free body diagrams of a civil engineering structure. Using data filtration we minimize the time dedicated to the graphical representations.

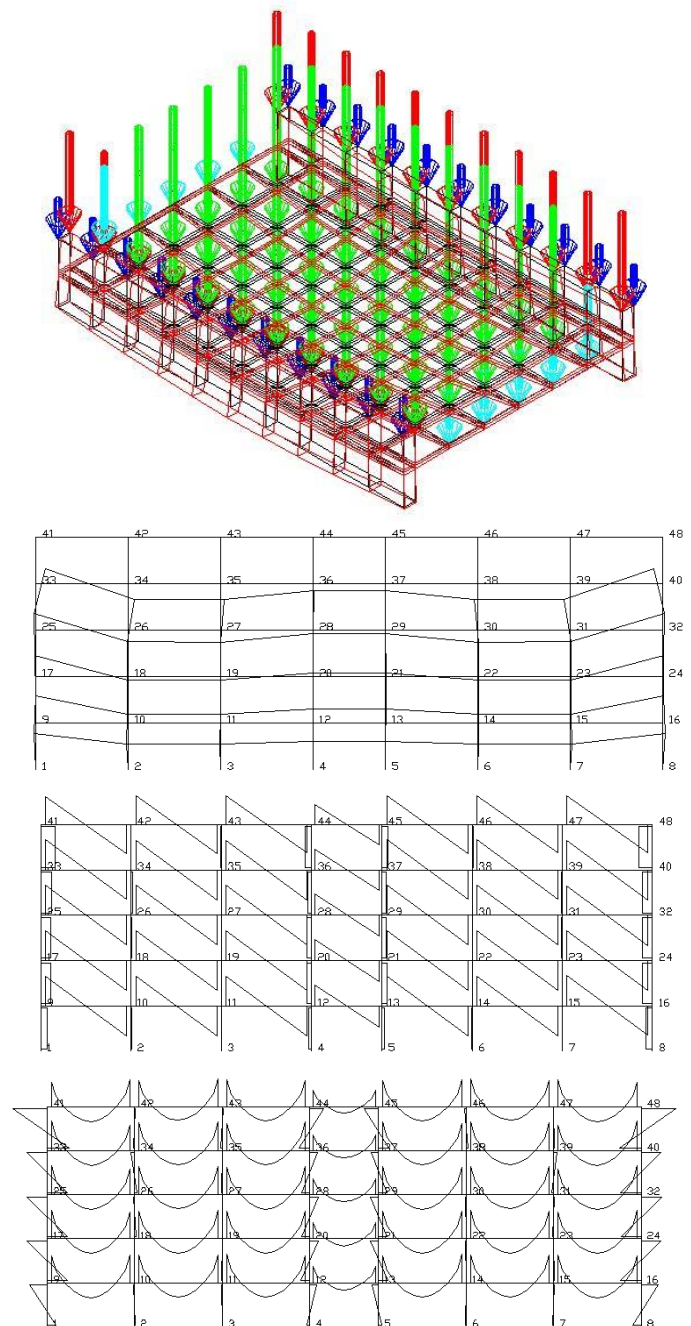


Fig. 2. Examples of data filtration for the optimization of the graphical post processing of the data using original software instruments

Analytical representation of the domains is a long run concern of the authors. Thus, an early endeavor to create computer based graphical representations of the geometrical 3D domains, i.e. CAD original applications, is presented in reference [7]. Thus, in section 4.8, pp. 268-290, and 4.9, pp. 291-295, are presented intersections between a cylinder and a tetrahedron, respectively a cone and a tetrahedron. Both, the cylinder and the cone are defined as ruled surfaces. Moreover, any polyhedron may be divided, i.e. sub-structured, in tetrahedrons. It results that the intersection between a line and a tetrahedron is the key solution for other intersections between some upper level generally defined surfaces. In addition, in 4.8 and 4.9 it was also solved the problem regarding the visibility of the intersection points.

One important problem to be solved was to include in the set of the intersection points only the points which are strictly included in the triangle, i.e. into the face of the tetrahedron, and to eliminate the other points. The solution of this problem is general and it is important for 2D domains, i.e. simple shapes which define a cross section, on the simple shapes being pre-defined positions of the points where the important stresses might appear.

In this way, let us consider that the tetrahedron is defined by the distinct points (x_i, y_i, z_i) , (x_j, y_j, z_j) , (x_k, y_k, z_k) , and (x_m, y_m, z_m) . The equation of the plane defined by the points (x_i, y_i, z_i) , (x_j, y_j, z_j) and (x_k, y_k, z_k) , where $i \neq j \neq k \neq i$ is:

$$f_{ijk}(x, y, z) = \begin{vmatrix} x & y & z & 1 \\ x_i & y_i & z_i & 1 \\ x_j & y_j & z_j & 1 \\ x_k & y_k & z_k & 1 \end{vmatrix} \quad (1)$$

With respect to the general equation of a plane, $f(x, y, z)$, the space is divided in a semi-space for which $f(x, y, z) > 0$ and a semi-space where $f(x, y, z) < 0$.

Let us consider a point $P(x_p, y_p, z_p)$ which is the result of the intersection between a line and the $i-j-k$ plane. If this point is located inside the $i-j-k$ triangle, this means that it an intersection point between the tetrahedron and the line. The condition which must be fulfilled by this point, in order to be inside the $i-j-k$ triangle or on its boundary is:

$$\left[f_{ijm}(x_p, y_p, z_p) \cdot f_{ijm}(x_k, y_k, z_k) \geq 0 \right] \text{and} \\ \left[f_{ikm}(x_p, y_p, z_p) \cdot f_{ikm}(x_j, y_j, z_j) \geq 0 \right] \text{and} \\ \left[f_{jkm}(x_p, y_p, z_p) \cdot f_{jkm}(x_i, y_i, z_i) \geq 0 \right] = \text{true} \quad (2)$$

This condition means that point P must be on the same side with the third point, with respect to the other planes of the tetrahedron, which are different of the $i-j-k$ plane.

For 2D problems, instead of a plane we have a line defined by points (x_i, y_i) , (x_j, y_j) and the point of reference $R(x_R, y_R)$. The according equation is:

$$f_{ij}(x, y) = \begin{vmatrix} x & y & 1 \\ x_i & y_i & 1 \\ x_j & y_j & 1 \end{vmatrix} \quad (3)$$

The condition that a generally located point $P(x_p, y_p)$ to be on the same side as point R , is:

$$f_{ij}(x_p, y_p) \cdot f_{ij}(x_R, y_R) \geq 0 \quad (4)$$

Once a 2D domain is expressed as a set of convex polygons, there may be decided if a point P is inside the polygon. The according condition is that point P must be on the same side with the centroid with respect to all the sides of the convex polygon.

A first application regards the selection of an entire 'map' or domain if the point where the click was performed is inside the domain. This means that the domain is expressed as a set of convex polygons. Another application is for cross sections of a beam which may be divided in a set of simple shapes, hollow or solid. This problem is far more important when we want to compute the most relevant values of the stresses in this generally defined section.

3. DISCUSSIONS

The calculus of the stresses is a long run concern of the authors, [8, 9]. One of the most important problems regards the automatic design, i.e. calculus of the most relevant stresses in the section. We consider that the normal stresses are produced by the axial force and by the bending moments, while the tangential stresses are produced by the shear forces.

Composite and inhomogeneous cross section may be divided in simple shapes, such as those in Fig. 3. For these simple shapes we can notice the areas where the maximum stresses may occur, even they are regarded as standalone sections or they are components of a composite section. Based on this remark we assign a set of point to each simple shape.

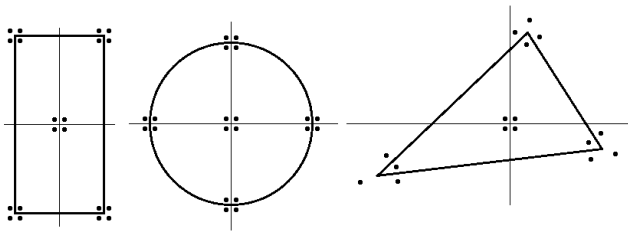


Fig. 3. Simple shapes and the locations of the points where the maximum stresses may occur

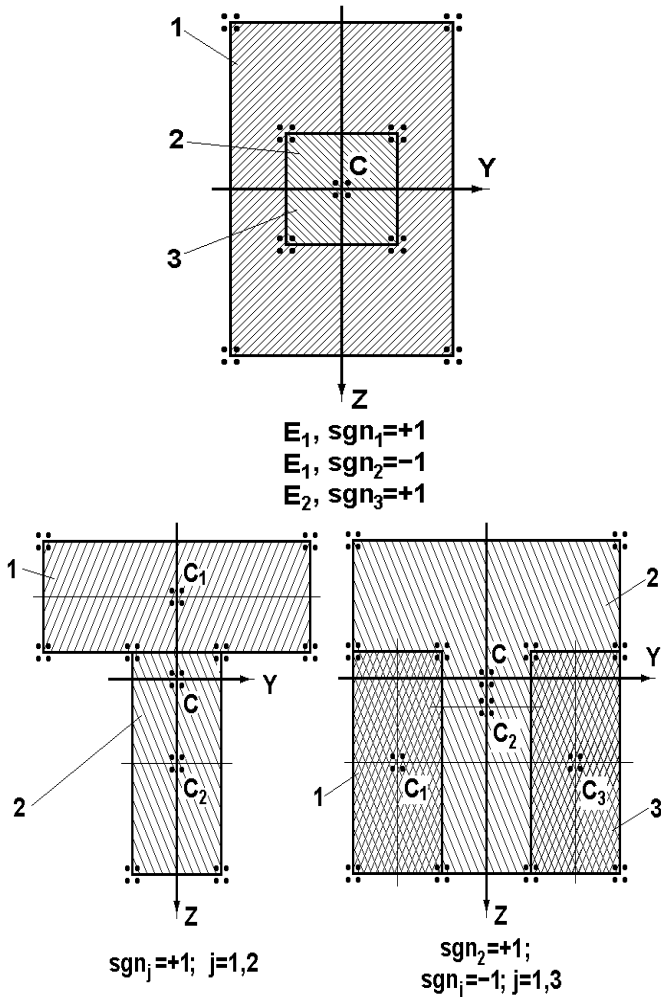


Fig. 4. Division of a section, either homogeneous, or inhomogeneous, in solid ($\text{sgn} = +1$) and hollow ($\text{sgn} = -1$) simple shapes

We define the reunion of the sets of points belonging to each simple shape in which the composite section is divided. Then we eliminate the points, based on the following rules:

- points which have the same coordinates, i.e. points which are not distinct;
- points which are not located inside a simple shape, except those which are next to the centroid of the section.

In addition to these points, there must be also considered the points where the parallels to the

neutral axis are tangent to the boundary of the cross section.

For the calculus of the stresses in a given point, there must be known the material constants of the material which includes that point. To solve this problem there are disregarded the shapes which include the point having the same material constants but having alternate signs, i.e. one is solid and the other is subtracted from the first one. Finally, the point will be included in a unique simple shape and the material constants assigned to this shape will be used for the calculus of the stresses, Fig. 4.

4. CONCLUSIONS

Nowadays advanced calculus instruments may be used to create original computer based analytical models. For these models there are no problems such as: the stability of the numerical algorithm, increased running time of the application because of the large number of iterations to be performed, large expenses as the experimental studies require. The method may take full advantage of the parallel processing and on other advanced data processing techniques and it can be easily included in automatic CAD systems. Moreover, there are several online projects based on the GNU license which may support this direction of development, such as GMP, CGAL and OpenGL.

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