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STUDY REGARDING THE DATA ASSEMBLING PROCESS FOR COMPUTER AIDED ENGINEERING APPLICATIONS

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Abstract: The creation of the computer based models in engineering may lead to the creation of a system of equations which must be solved. There are several examples in structural studies when either analytic approaches or numerical methods are producing systems of equations. Among these cases, we may identify a particular set of cases where the unknowns are grouped in certain points, designated nodes. In this way, we may consider the following cases: interpolation which uses spline functions, deflected shape of straight bar modelled either by the use of the method of initial parameters, or using the finite difference method, displacements of a thin plate using the finite difference method. The paper presents an analysis of this particular type of models and presents solutions regarding a strategy to conceive a general data structure which may be used for the rapid development of software applications. The definition of the data type takes into consideration the nodal parameters, identifiers of these nodal parameters, flags of these nodal parameters and others. There were identified two types of equations which use this node-wise information. A first class of equations is connecting the parameters of the same node. The second class of relations connects the same type of parameters belonging to two adjacent nodes. For instance, in the case of the method of initial parameters we have the laws of variation of the shear forces, of the bending moments, of the rotations and of the displacements. Following these ideas, there is proposed a general approach to define the nodal data as a data type to be used in the classes oriented programming languages widely used nowadays. One of the most important consequences is the creation of the software library used as a foundation for the development of intelligent software instruments. It must take into account all the parameters that influence the phenomenon under investigation, and it also has open-system features and leads to the development of flexible cross-platform software libraries to be used in various other directions. Last but not least, there should be reminded that the paper is based on an extensive experience in software development of turn-key software instruments for engineering problems.

Key words: data assembling process, high flexibility, original data types.

1. INTRODUCTION

The Original computer aided solutions in engineering may use either analytic approaches, or numerical methods. Because of the extensive use of the computers, numerical methods are the most frequently used modeling techniques nowadays. The accuracy of a numerical model depends on several criteria, an important aspect being connected to the discretization of the domain in which the phenomenon is produced. It is known that the larger number of discretization components are used, the more accurate the model becomes. By components we mean points, areas, finite elements etc.

This approach regarding the use of a large number of discretization components leads to large systems of equations to be solved. In order to easily handle large amounts of data defined at the mathematical level as matrices, we have conceived and developed: particular data types, [1, 5], data processing techniques, [3, 4] and general software libraries [2, 6].

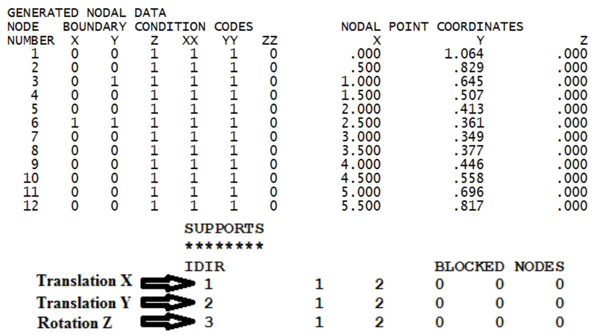
However, a complementary paradigm must be conceived in order to offer advanced instruments for the rapid development of original computer based instruments in engineering. This new paradigm must offer reusable software resources, which must be general in order to be easily adapted for particular projects and flexible in order to be optimized to fulfill a given objective.

Starting from these general directions, there must be identified concrete criteria to be used in the development of the new software solution, criteria resulted from a thorough analysis of the problems envisioned to be solved.

2. IDEAS REGARDING THE CLASS OF PROBLEMS TO BE SOLVED

As mentioned before, a numerical model leads, most of the time, to a system of equations which must be solved. It is interesting to analyze the way how this system of equations is created and to conceive instruments which offer facilities in the readily creation of the system. This means to conceive a general method which may be applied in the design of the numerical models that may be implemented as software instruments.

An interesting aspect previously mentioned regards the discretization in a large number of components: nodes, areas, finite elements etc. All these entities are defined by particular sets of data, depending of the problem to be solved. It results that a general method to handle the data assigned to these entities would be helpful in the easily development of a software solution. Before proposing a concept regarding the solution, let us analyze the data sets used in different numerical methods and models.


GENERATED NODAL DATA

NODE NUMBER	BOUNDARY CONDITION CODES X	Y	Z	XX	YY	ZZ	NODAL POINT COORDINATES X	Y	Z
1	0	0	1	1	1	0	.000	1.064	.000
2	0	0	1	1	1	0	.500	.829	.000
3	0	1	1	1	1	0	1.000	.645	.000
4	0	0	1	1	1	0	1.500	.507	.000
5	0	0	1	1	1	0	2.000	.413	.000
6	1	1	1	1	1	0	2.500	.361	.000
7	0	0	1	1	1	0	3.000	.349	.000
8	0	0	1	1	1	0	3.500	.377	.000
9	0	0	1	1	1	0	4.000	.446	.000
10	0	0	1	1	1	0	4.500	.558	.000
11	0	0	1	1	1	0	5.000	.696	.000
12	0	0	1	1	1	0	5.500	.817	.000

SUPPORTS
****

	IDIR			BLOCKED NODES		
Translation X	1	1	2	0	0	0
Translation Y	2	1	2	0	0	0
Rotation Z	3	1	2	0	0	0

Fig. 1. Example regarding some of the nodal data in two FEM applications

In the finite element method the continuum is replaced by a discrete domain made of finite elements which are defined, among other attributes, by their nodes. Nodes are defined by an identifier, the coordinates in a general system of axes and other node-related parameters, such as flags regarding the blocked degrees of freedom or output information, such as temperature or displacements. Moreover, in the same finite element model the temperature is considered a nodal unknown and after the heat transfer study is completed, it becomes an input data for the second study, dedicated to the calculus of the thermal stresses, [7]. It results that a nodal attribute may have one of the following statuses: 'do not consider / comment', input data, unknown, output data. The status may be symbolized by a flag parameter assigned to the current attribute. Similar aspects may be noticed about the definition of the finite elements, which may include for a beam-type element: identifier, identifiers of the nodes, identifier of the geometrical characteristics, identifier of material constants etc.

Another numerical method used in engineering is the finite difference method, [8]. Figure 2 presents some of the results of a CFD problem solved using an original software, where, among other nodal parameters, we use the u and v components of the speed of the fluid. Several fluid mechanics problems were solved using the same finite difference scheme and the conclusion was that the method is stable, reliable and accurate.

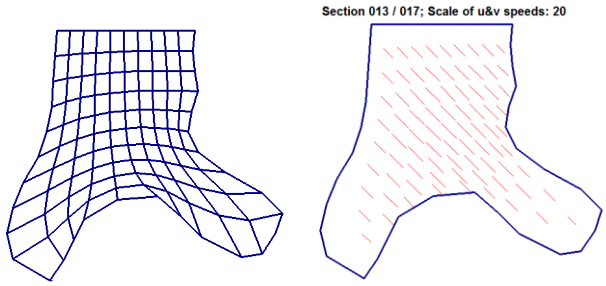


Fig. 2. In a fluid dynamics problem solved using the finite difference method some of the nodal parameters are the u & v speed components of the fluid

Beside the finite element method and the finite difference method, let us consider another type of problem which uses the spline functions in order to solve an interpolation problem. Let us consider a general function which is approximated using $N+1$ points, i.e. N intervals, on the $\lfloor x_i, x_j \rfloor$ interval the spline function $f_i : \lfloor x_i, x_j \rfloor \rightarrow \lfloor y_i, y_j \rfloor$, [9], being defined as:

$$y = f_i(x) = A_i \cdot (x - x_i)^3 + B_i \cdot (x - x_i)^2 + C_i \cdot (x - x_i) + D_i \quad (1)$$

where the coefficients A_i, B_i, C_i, D_i are unknown. The first and the second derivatives may be easily derived.

In order to compute the A_i, B_i, C_i, D_i unknown coefficients for each interval, there must be used 4 equations, with several types of conditions, for each end of the 'i', 'j' intervals: condition that the f_i function passes through the (x_i, y_i) and (x_j, y_j) points and conditions regarding the continuity of the slope and of the curvature in both ends of the interval. Considering that the curvature is nil at both ends of the curve to be interpolated, the number of unknowns is:

$$\underbrace{2}_{\substack{first\\node}} + \underbrace{(N-1)}_{\substack{interior\\nodes}} \cdot 4 + \underbrace{2}_{\substack{final\\node}} = 4 \cdot N \quad (2)$$

It results that for N intervals we have $4 \cdot N$ unknowns and $4 \cdot N$ equations, which means that the resulting system of equations is compatible and determinate.

In this case the nodal parameters are the coordinates, the slope and the curvature.

Finally, let us consider some aspects regarding an analytic model based on the method of initial parameters of a beam on elastic supports, [10].

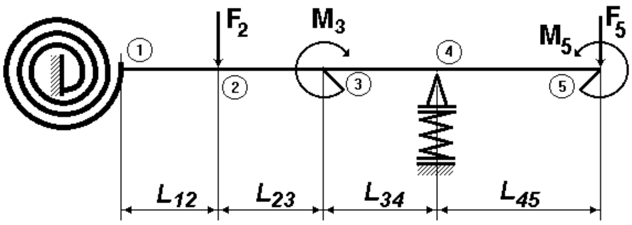


Fig. 3. Example of a statically indeterminate system which uses elastic supports

For the beam presented in figure 3 the analytic solution uses the method of initial parameters in order to deduce the laws of variation of the displacement and of the rotation along the beam. In this case the unknowns are the reactions $M_{Y\,1}$, $V_{Z\,1}$, $V_{Z\,4}$ and two integration constants which are closely related to the physical condition regarding the shape of the beam next to the supports and the boundary conditions regarding the values of the internal forces and moments (in section 5). We must take into consideration the elastic supports, i.e. the connection between the reaction and the according displacement for a given section 'i',

$$\begin{cases} H_{X\,i} = k_{u_X\,i} \cdot u_{X\,i} \\ V_{Y\,i} = k_{u_Y\,i} \cdot u_{Y\,i} \\ V_{Z\,i} = k_{u_Z\,i} \cdot u_{Z\,i} \end{cases} \quad \begin{cases} M_{X\,i} = k_{\varphi_X\,i} \cdot \varphi_{X\,i} \\ M_{Y\,i} = k_{\varphi_Y\,i} \cdot \varphi_{Y\,i} \\ M_{Z\,i} = k_{\varphi_Z\,i} \cdot \varphi_{Z\,i} \end{cases} \qquad (3)$$

We do not elaborate on the methods to solve this problem, being interested in the nodal parameters of all the sections. Thus, according to reference [10], there are 28 nodal parameters, to say nothing about the geometrical coordinates which identify the node, the flag parameters and the data used to connect the adjacent nodes.

3. DISCUSSIONS

In the previous section several computer based original solutions were analyzed, some of them being already implemented. These solutions use general numerical methods, analytical models and numerical methods in engineering, i.e. FEM and FDM. In an initial approach we notice that they require a node-wise data structure, which must store a given, not specified, number of attributes, together with their according set of flags. The flags identify the unknowns of the problem, in order to automatically create the system of equations, according to the equations or the principles which are governing the phenomenon under investigation.

An early solution to define the necessary data types employed to design the data model of an application is presented in figure 4. As it can be noticed, first are defined the so-called 'basic' data types and then the higher complexity data types. It was preferable to start with a simpler approach, which can be easily tested, and at a later stage to conceive and develop solutions based on dynamic memory allocation.

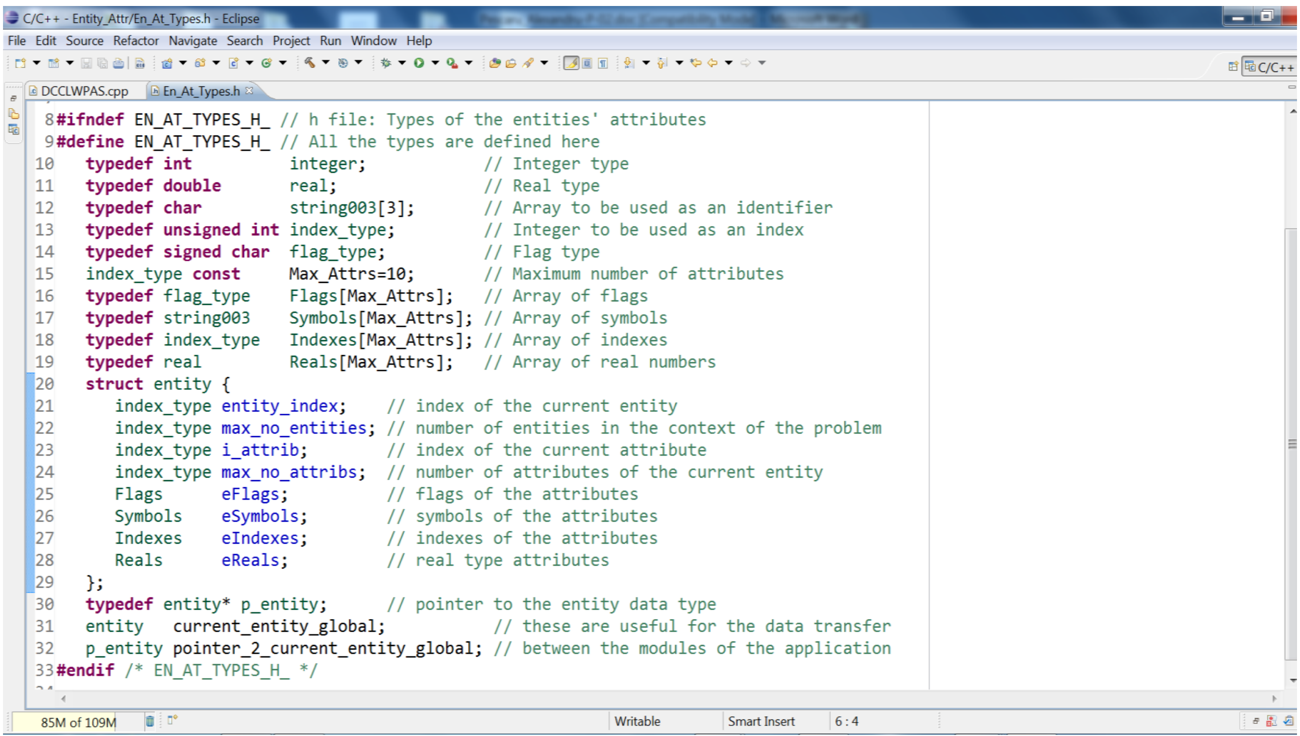


Fig. 4. An initial definition of the entities' attributes data types

Using these data types which model the multiple attributes of the various entities, there may be automatically generated the mathematical form of the problem, that already have analytical or numerical solutions. In this way, the assemblation process for the problems presented in the previous section may be easily defined as an algorithm which elegantly operates with upper level notions. Moreover, the development of the according code may be considered a 'consequence' of the upper level understanding of the problem and of the intelligent instruments that are used.

4. CONCLUSIONS

According to Larry Wall, [11], the three great virtues of a programmer may be understood as an intelligent strategy to structure the software instruments which will require less maintenance effort. Generality, flexibility and reusability depend on the vision regarding the data model of the application. Once the data types have abstract definitions and the according data processing libraries are created, the development of the upper level particular applications is not a complex and demanding task anymore. It requires hard work and experience to customize the general application already written and eventually to develop some particular solutions.

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