A Graphic Tool For Structural Analysis of Linear Element Models with an OOP Approach

Rafael L. Rangel, Pedro C. Lopes, Luiz Fernando Martha

Tecgraf Institute of Technical-Scientific Software Development of PUC-Rio
(Tecgraf/PUC-Rio)

INTRODUCTION

Computer-based methods, such as the Finite Element Method (FEM), are best learned when working at the source code level.

Although there are several open source programs, few of them have a code structure that allows for an easy understanding, maintenance and expansion.

The goal of this work was to develop a tool for linear-elastic analysis of reticulated models, using the Direct Stiffness Method, a FEM version for bar and beam elements. This tool is designed to be used in structural analysis courses and aims to supply the lack of appropriate programs by focusing on didactics algorithms and a formal software engineering design.

To achieve this, the MATLAB environment and the Object Oriented Programming (OOP) paradigm were used to develop the LESM program [1].

RETICULATED MODELS

The LESM program handles 5 types of reticulated models: Truss 2D/3D, frame 2D/3D, and grillage. Trusses are made by bars, which have only axial behavior. Frames and grillages are made by beams, which may have axial, torsional, and flexural behaviors.

In a linear analysis, these behaviors are uncoupled, so the displacements/rotations resulting from each one are given by an independent differential equation.

For models in which the elements exhibit flexural behavior, two formulations are considered to describe the bending of beams: Euler-Bernoulli and Timoshenko theories (Figure 1).

These formulations can be unified by introducing auxiliary parameters, following the developments of [2], which are based on the Timoshenko's dimensionless parameter that relates bending rigidity with shear rigidity, and is null in Euler-Bernoulli's theory:

$$\Omega = \frac{EI}{GA_s l^2}$$

Thus, the expressions for shape functions, fixed-end-forces, and stiffness coefficients become the same for both theories. These generic expressions can be found in the LESM source code and in [3].
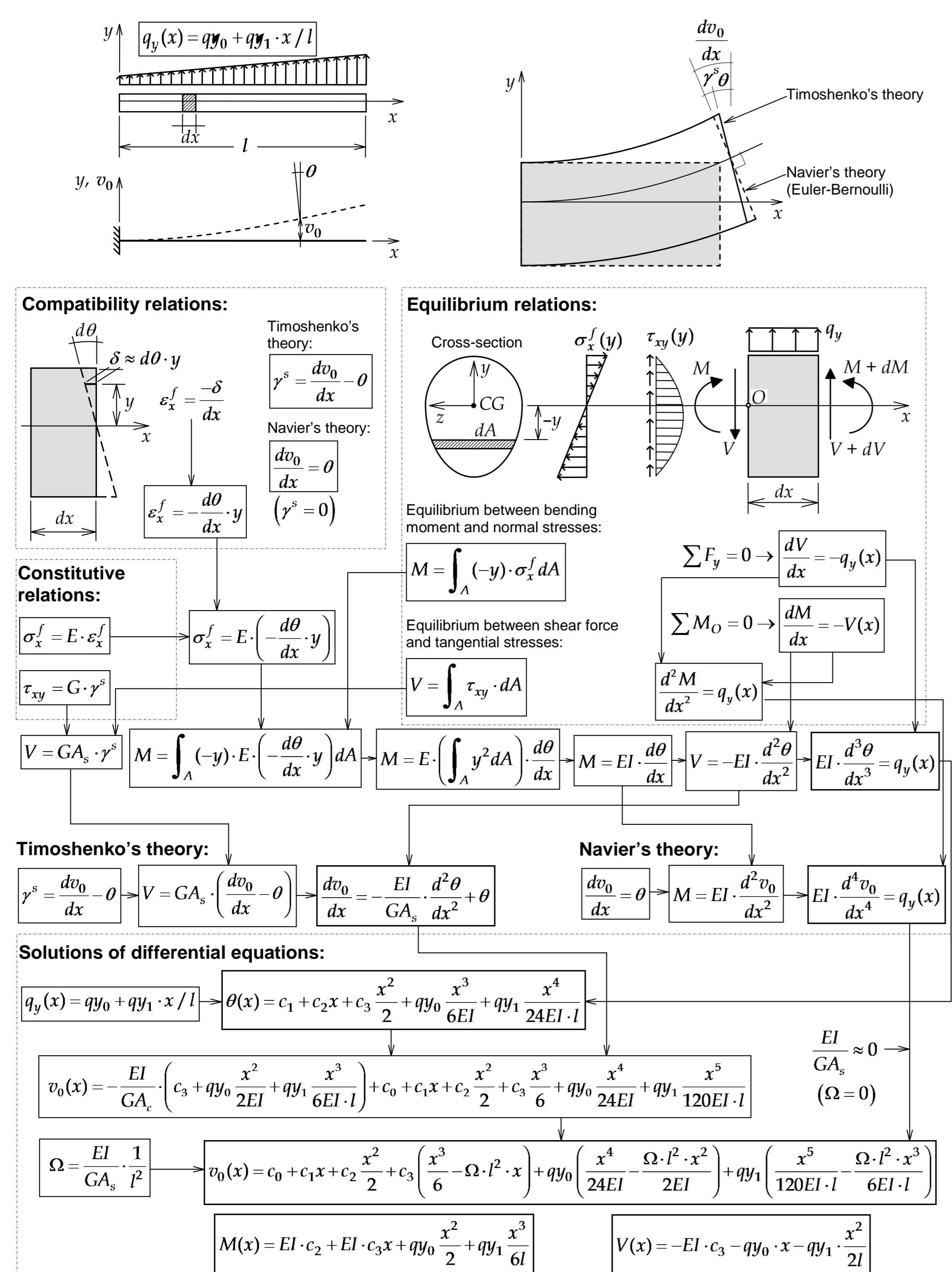

Fig. 1 - Idealization of flexural behavior of beam elements

OOP CLASS ARCHITECTURE

To manage these different types of models and element behaviors, the proposed classes are shown in Figure 2.

The definition of the Analysis Model (*Anm*) class, responsible for dealing with particular aspects of each model in its sub-classes, allows a generic treatment of the model.

In spite of using generic expressions for bending behavior, distinct sub-classes were adopted for elements to emphasize symmetry between the expressions from both theories.

The element behavior was also split into two classes, one for dealing with its mechanical properties (*Elem*), and another for its loading behavior (*Lelem*).
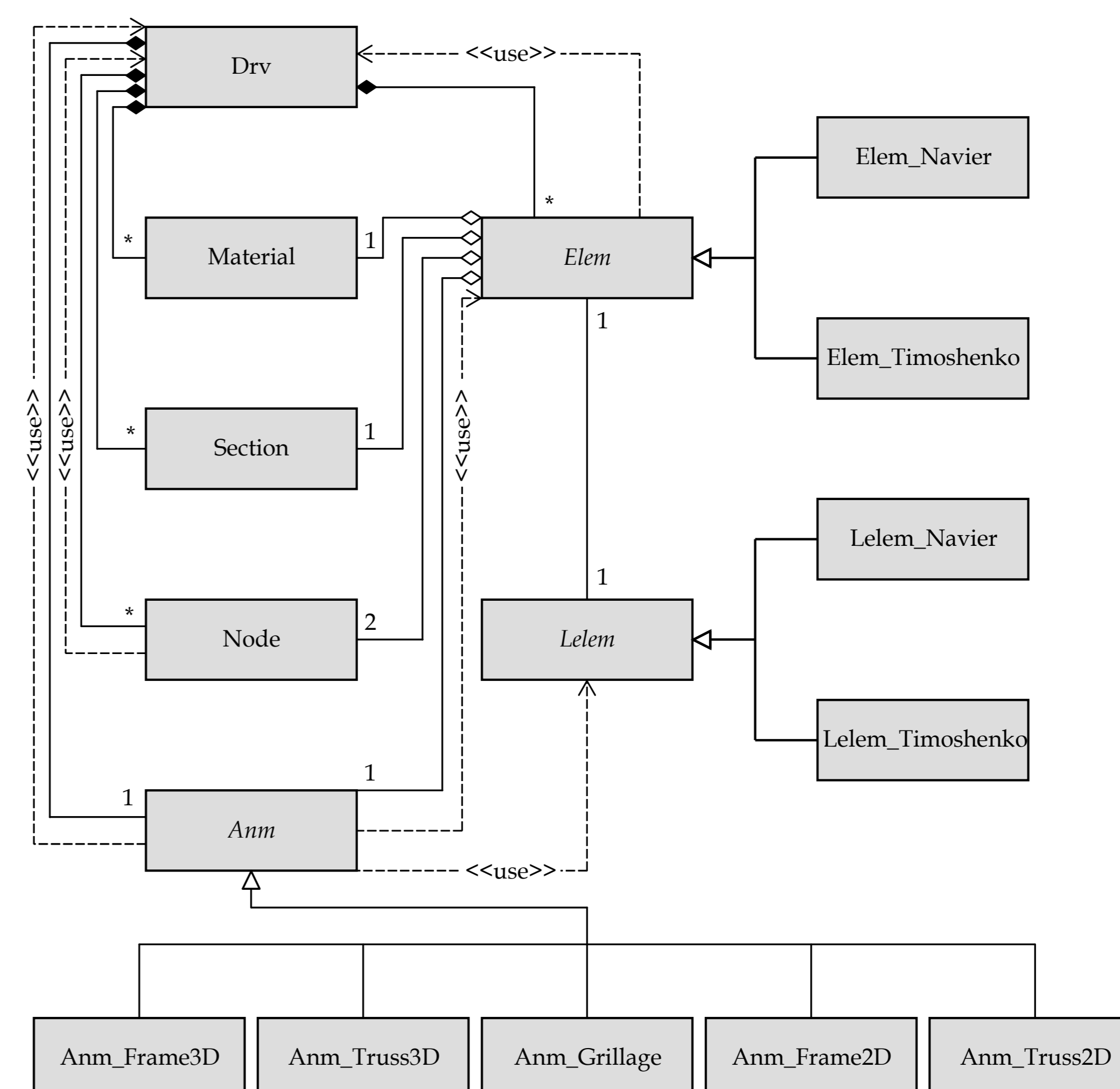

Fig. 2 – UML class diagram of the LESM program

GRAPHICAL USER INTERFACE

To give a practical use to the program, a graphical user interface (Figure 3) was developed completely in the MATLAB environment.
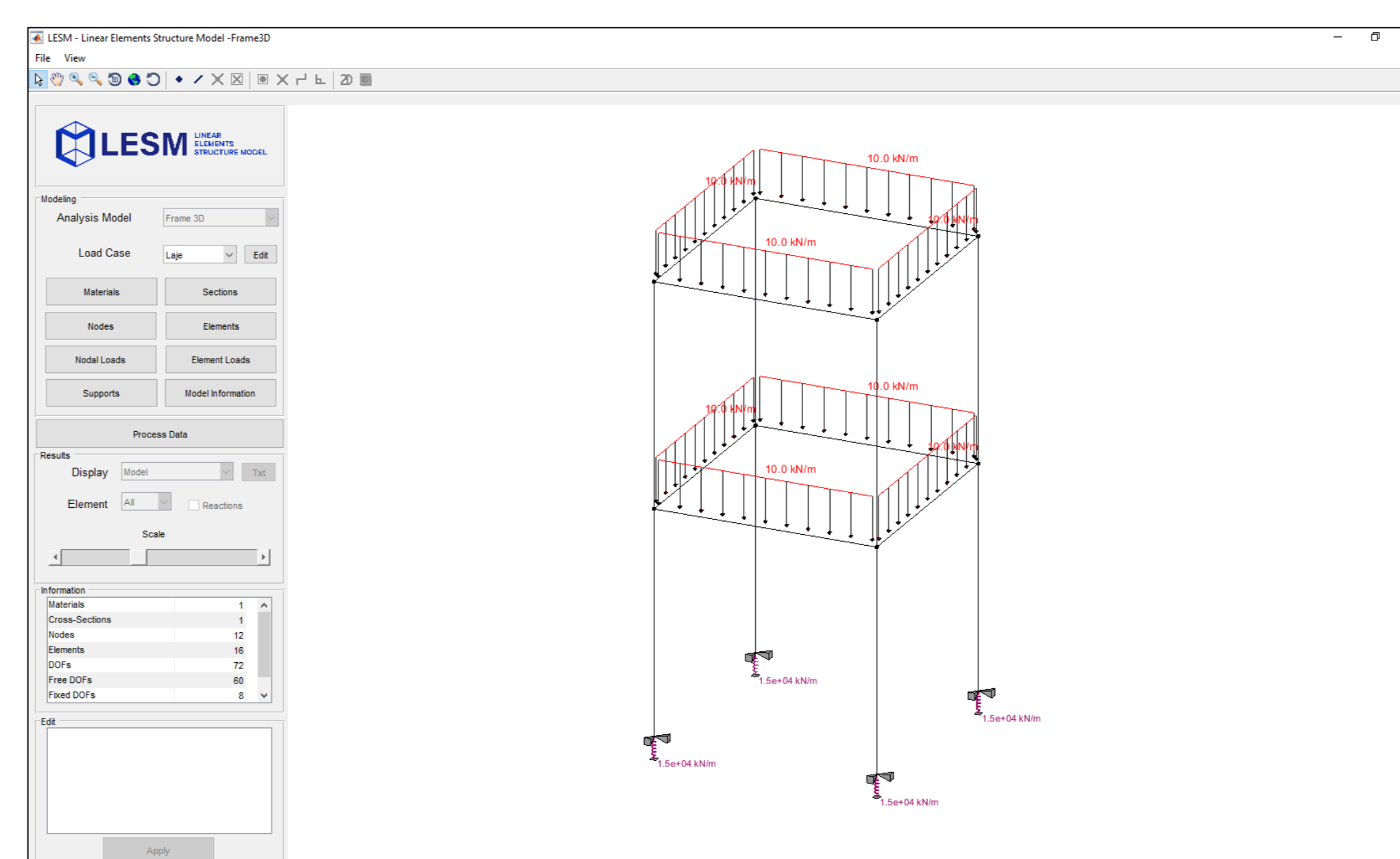

Computer graphics and computational geometry algorithms were also implemented to allow users manipulate both 2D and 3D models with mouse interaction.

Fig. 3 – User interface of LESM

CONCLUSIONS

The use of the LESM program in undergraduate and graduate courses proved that the proposed OOP classes, for this particular engineering context, provides a close integration between structural analysis theory and its computer implementation. Furthermore, the inclusion of new features to the program becomes much faster and easier.

REFERENCES

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