
AN INTERACTIVE-GRAPHICS TOOL FOR MODELING AND ANALYZING STRUCTURES IN MATLAB

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This work presents a user-friendly graphic tool, entirely implemented via MATLAB, based on the Object-Oriented Programming (OOP) paradigm, for linear-elastic analysis of one-dimensional element models (reticulated models), such as frames, trusses, and grillages, using the direct stiffness method. The creation of this program has two main goals. The first is an educational approach, which aims to provide students a comprehensive program for better understanding the process of matrix structural analysis, through a didactic and well-documented open source code. The OOP paradigm grants generality and modularity to the code, which, combined with the high-level MATLAB programming language, allows any user to understand procedures and implement new ones with relative simplicity.

The second goal, which is the focus of discussion on this article, is the development of a graphic tool for practical use. A graphical user interface (GUI) of simple usage and multiple functionalities combined with computer graphics techniques allow students and professionals to model, simulate, visualize, and analyze several types of linear element models. The existence of a user interface and a structure modeler complement the educational appeal of the program since the graphical visualization of the analysis results gives students a better understanding about the behavior of reticulated models, and may help teachers in providing such insight during classes. In addition, it is a great facilitator for civil and mechanical engineers whose aim is to obtain results for designing structures.

The LESM (Linear Elements Structure Model) program was developed at the Department of Civil and Environmental Engineering of Pontifical Catholic University of Rio de Janeiro (PUC-Rio) and at the Institute of Technical-Scientific Software Development of PUC-Rio (Tecgraf/PUC-Rio) [1,2]. The LESM program has been successfully used in some structural analysis courses at PUC-Rio as a modeling and analyzing program for studying structures behaviors. The full documentation of the program, as well as a download link is available at www.tecgraf.puc-rio.br/lesm.

Some features of the modeling and analysis options of the LESM program are the consideration of:

- Five types of analysis models: plane truss, spatial truss, plane frame, spatial frame, and grillage;
- Two types of bending behavior of linear elements: Euler-Bernoulli and Timoshenko bending behavior;
- Four load types: concentrated force or moment, uniformly distributed load, linearly distributed load, and temperature variation effects;
- Rigid or flexible (spring) supports;
- Creation of load cases and their combinations;

The interface of the program was created using the Graphical User Interface Development Environment (GUIDE) of MATLAB, a drag-and-drop tool for laying out user interfaces whose behavior are controlled by callback functions that are called upon a specific event based on the event-driven programming paradigm. The program is composed by a main dialog window (see Figure 1) and nine auxiliary dialog windows for modeling structures by entering the necessary input data. The main dialog holds an *axes*, a MATLAB interface component that defines the area where the graphic system can plot geometric primitives such as points, lines, polygons, etc., to represent the structural model and analysis results. This plotting area for displaying the model and the results are also known as canvas.

An important feature of the LESM program is the mouse interaction with the canvas to draw the model topology, pick objects to assign information to them, and manipulate the visualization to apply camera rotation, zooming, etc. Mouse interactions configure an important aspect of modeling structures, by using mouse clicks and movements on a canvas, the task of modeling and analyzing results becomes intuitive and faster.

The program handles mouse events by creating objects of an inherited subclass from the generic superclass *EMouse* [3]. This is an abstract class to facilitate the development of MATLAB applications that handle mouse events on canvases. It declares abstract methods that associate callback functions to basic mouse actions, and its use is achieved by creating a client subclass that inherits its properties and implements its abstract methods. Two subclasses were inherited to manage the mouse events, one for 2D models and another for 3D models. The visualization functionalities, such as pan and zoom, are implemented by both plane and spatial models, while modeling options are restricted to the 2D subclass. The modeling of 3D structures takes place in 2D projections specified by the user.

Once mouse modeling is enabled, some computer graphics issues surface and need to be dealt with. In that matter, one of the main questions a linear element analysis program has to face is the treatment of crossing elements and nodes, and collinear elements. This issue was solved with computational geometry methods.

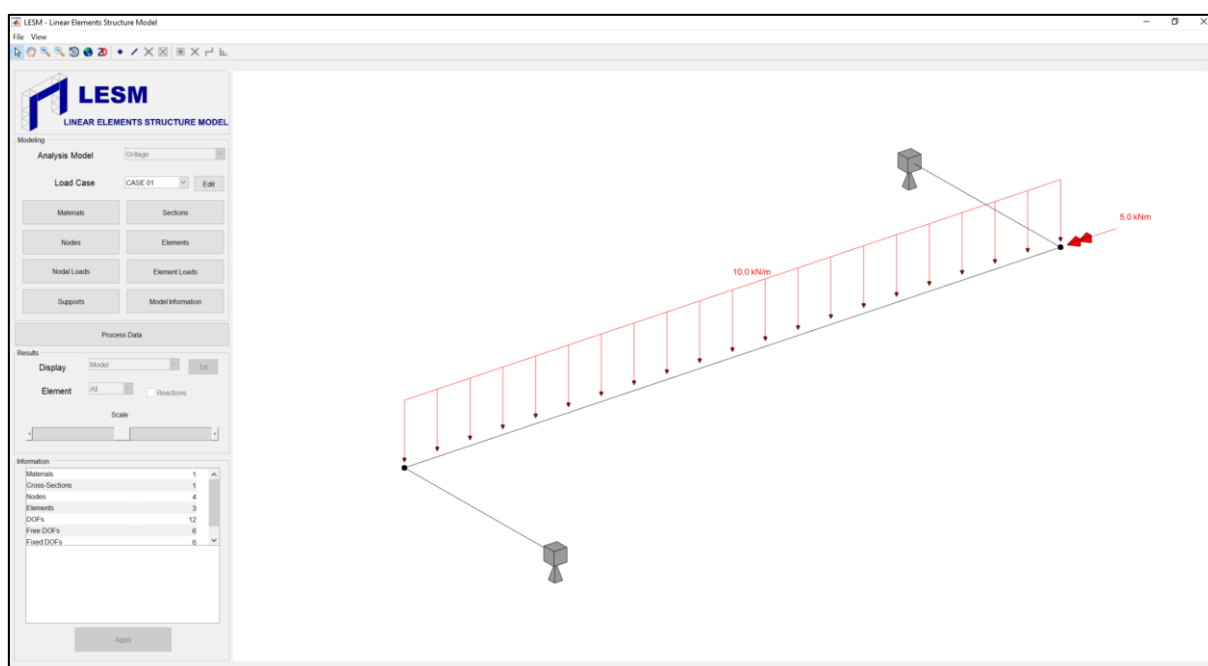


Figure 1: Main dialog window of the graphical user interface

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