

THE INTERACTIVE GEOMETRIC SOFTWARE - A MODERN TOOL IN FORMING AND DEVELOPMENT OF THE ENGINEERING THINKING

Abstract: The purpose of the paper is to highlight the great applications of the interactive geometric software in exploring and thoroughgoing study of some chapters of applied mechanics.

In first part of the paper is presented advantages of using interactive geometric software in training and development of the engineering thinking, as well as the main chapters of applied mechanics in which the use of these software environments is recommended.

Following are detailed case studies that illustrate the using an interactive geometric software in applied mechanics.

At the end of the paper, the author's observations and conclusions are given.

Key words: Interactive geometric software, engineering thinking, applied mechanics.

1. INTRODUCTION

According to some studies, [1], the information that a human being perceives from the environment by means of the five senses, is distributed (in percentages) as in Figure

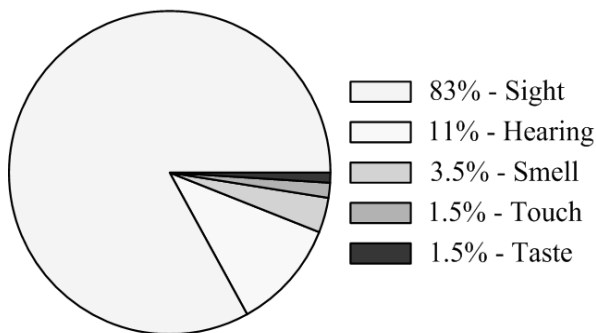


Fig. 1 Percentage distribution of information perceived by the human being

In addition to the above, according to the same studies, man retains about 10% of what he hears, 20% of what he reads, and 80% of what he sees. At the same time, images are processed by the human brain about 60000 faster than the written text.

As a result, the particular importance of graphic information is revealed. In this context, it is not by chance that the most effective learning methods use intensive graphical representations.

Technical engineering is an area where graphic representations are irreplaceable. In this regard, eloquent examples are the technical drawing, 3D representations of the bodies and representation by color maps of stresses and displacements distributions in finite element analysis. It follows that the engineer's thinking is strongly anchored in graphical visualization.

With the advent of the electronic computer and the first scientific programming languages, the numerical solving of many engineering problems has become an increasingly used option. In this context, numerical computation has found many applications in engineering. Thus, in many cases, the graphical solving of the

problem (if this solving exists) was dropped and was adopted numerical solving with great enthusiasm.

Under these circumstances, the formation and development of engineering thought became slow processes, because they had no graphical, intuitive support.

The continuous development of computer graphics has created the prerequisites for the reinvigoration of graphic methods to solve some problems in technical engineering, thus contributing to the accelerated formation and development of engineering thinking.

2. ADVANTAGES OF GRAPHICAL METHODS IN RELATION TO NUMERICAL METHODS

Graphical problem-solving methods, as well as graphical visualization of results based on algebraic or numerical methods, offer a number of advantages, the most important of which are:

- Encompassing of the problem in its entirety in a single graphical representation.
- The results of problem solving are suggestive.
- The mistakes made during problem solving are easy to detect, often making geometric construction impossible.
- Gives to engineering thinking a logical basis for problem solving, much more persistent over time than for algebra or numerical methods.
- Graphical problem-solving methods are an excellent training for engineering thinking, stimulating logical thinking and coherent mental structure of information.

The most often invoked disadvantage of graphical methods is related to the limited accuracy of the results which is depending on the accuracy of the measurements on the drawings.

Using interactive geometric software eliminates this disadvantage because the measurements are virtual. As a result, the accuracy of the results is the same as the precision of the numerical results.

Moreover, making numerical calculations with greater precision than the precision required in practice is generally costly, laborious, and useless. This leads to an

extra argument for the use of graphical methods where their use is possible.

All of the above considerations lead to the conclusion that graphical representations and graphical methods for solving problems are topical, and their use is not only timely but also necessary.

2. GENERAL FEATURES OF GEOMETRIC INTERACTIVE SOFTWARES AND THEIR POSSIBLE USES IN ENGINEERING

According to an acceptable definition, geometric interactive software is a virtual mathematical platform that combines plane geometry, spatial geometry, numerical computation, and some symbolic calculations.

Currently are available numerous interactive geometric software, of which *Cinderella* and *GeoGebra* are highlighted, through the many powerful tools available to the user.

Cinderella was initially developed in Objective-C on the NeXT platform. Subsequently, the software is rewritten in Java, and in 1998 the Cinderella 1.0 school version appears. Pro version of this software is launched in 2012. This version, in addition to the geometric engine, includes a physics simulation engine and is free of charge from 2013.

According to [2], *GeoGebra* is an interactive mathematics software program for learning and teaching mathematics and science from primary school up to university level.

The first version of the *GeoGebra* software was launched in 2002. Currently, *GeoGebra* v6 software is available. This geometric interactive software is currently extensively used in pre-university and university environments around the world, largely due to its incontestable qualities, but also to the fact that this software is absolutely free.

It is noteworthy that about 90% of geometric interactive software current uses are focused on teaching and understanding mathematics, which is why this platform is sometimes referred to as a learning platform.

However, corroborating the visualization and manipulation capabilities of geometric constructions, there is an inadequate applicability in technical engineering of the currently available geometric interactive software.

The main capabilities of a current interactive geometric software are briefly detailed below.

Interactive geometry environment - is an interactive environment where geometric constructions can be made using entities such as lines, line segments, circular arcs, circles, etc. Geometric constructions can be interactively done by "drawing" them into the graphical window of the application or by introducing the analytical expressions of the entities into the algebraic input area.

Control of geometric constructions by sliders - A geometric construction is defined as a set of geometric entities, by their dimensions and their relative position.

As a result, the geometric construction can be modified (controlled) by altering the dimensions of the geometric entities and their relative position. Practically, the control is done by changing some numeric variables, representing distances or angular measures.

A simple, suggestive and a simultaneously visual way for controlling the numeric variables in a given range and with a given increment is the use of sliders. By simply positioning the cursor on the slider, the numerical variable is changed, so the geometric construction is changed in concordance to new value of the variable.

By activating the slider animation, the geometric construction changes dynamically, in concordance with the automatic change of the numeric value controlled by the slider.

Figure 2 gives an example of using a slider that controls the number of divisions of the interval where a defined integral is calculated. The division of the interval is used to highlight the Riemann sums (lower and upper sum) between which exists the exact value of the defined integral. Using this simple geometric construction, the student can visualize and understand without a doubt the sandwich theorem and the nature of the defined integral.

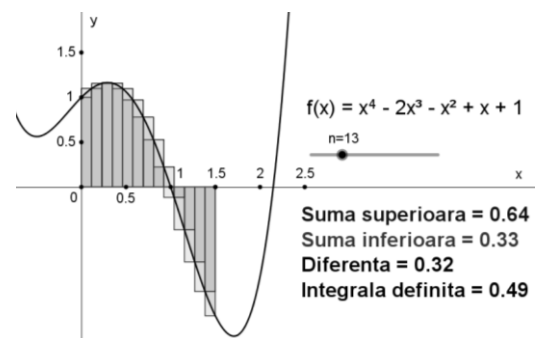


Fig. 2 Example of slider use

Tracking - Using this feature, it is possible to highlight the trace left by a geometric entity (usually a point) when the geometric construction is dynamically changed.

This feature is particularly applicable in the synthesis of planar mechanisms made of articulated bars. Thus, using this feature, it is possible to highlight the trajectory described by a point of the mechanism when the leading element moves into its motion domain. Changing the position of the leading element of the mechanism, manually or automatically by animation of a assigned slider, it is displayed the trace left by selected point. By appropriately changing the dimensions of the mechanism, a desired trace is obtained.

Figure 3 exemplifies the use of tracking feature for a plan quadrilateral mechanism. For the given mechanism, the point F was highlighted in two cases of lengths of the elements of the mechanism.

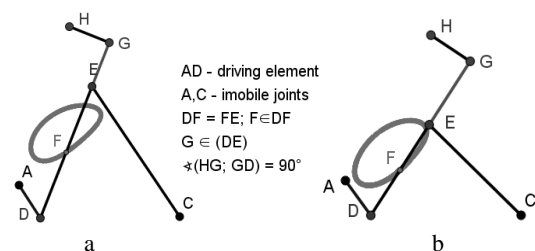


Fig. 3 Example of Tracking use

a - DE=3.6AD; EC=4AD, b - DE=2.5AD; EC=3AD

Locus - This feature is very similar to *Tracking* feature. Using this feature, it is possible to display the geometric locus described by a point of the geometric construction (driven point) in relation to the movement of another point (driving point) with which it is in a geometric relation.

The distinction between *Locus* and *Tracking* is that in order to obtain the geometric locus there is no need to change the position of the driving point. The simple invocation of the *Locus* tool with the two points (driving and driven point) leads to display of the sought geometric locus.

Both *Tracking* and *Locus* allow the drawing of the coupler curves, since they are nothing but geometric places. The usefulness of these two interactive geometric software features is more than obvious. In this context, plotting the dig backhoe diagram is extremely simple. Moreover, there is the possibility of controlling the geometry of the mechanism so as to obtain a digging diagram close to a desired optimum.

As an example of using the *Locus* feature, Figure 4 shows the curve described by mobile joint M of the mechanism known as the Chebyshev six-bar paradoxical mechanism, [3].

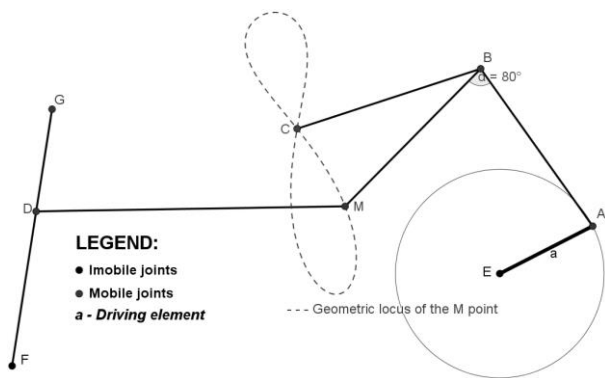


Fig. 4 Example of *Locus* use

It should be noted that determination of the trajectory point M in the above mentioned mechanism using numerical calculus methods is extremely laborious, because these methods are based on complicated mathematical relations between the coordinates of the point M and the coordinates of the point A.

Using the features of interactive geometric software to the kinematical optimization of the mechanisms, a geometric pre-optimization can be made in which a domain of relevant solutions is determined. After geometric pre-optimization, it is possible to improve it, using as input the narrow range of relevant solutions previously determined and numerical calculation methods.

Other capabilities of interactive geometric software are as follows:

- The possibility of displaying the analytical equations associated to geometrical entities;
- The possibility to use spreadsheets, very similar with Excel spreadsheets;

- The possibility of creating user-defined tools, "covering" a set of steps of a geometric construction and that are automatically generated when invoking the tool;
- The possibility of creating scripts that allows the automation of tasks.

In addition to the above, it has to be underlined that interactive geometric software represents the ideal framework for the revival of the *Graphic Statics* (highly suggestive and much closer to mechanical engineer thinking than analytical methods). *Graphic Statics* has been increasingly neglected, along with the upward trend of the numerical calculus performance of the computer.

As a result, the geometric interactive software has applicability in all disciplines where can be used *Graphic Statics*: theoretical mechanics, strength of materials, theory of mechanisms, etc.

Figure 5 gives an example of using the *Graphic Statics* methods to determine the resultant force from a parallel force system and the reaction forces of a bar with simple supports at ends.

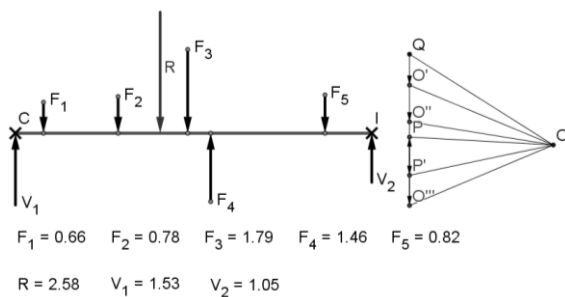


Fig. 5 Example of using *Graphic Statics* in interactive geometric software

It should also be noted that the current developments of the interactive geometric software have as target an expansion to spatial geometry. In this regard, GeoGebra made this step, starting with version 5.

By switching to spatial geometric constructions a wide field of applicability of this type of software is opened in mechanical engineering (*Graphic Statics* in 3D, analysis and synthesis of 3D articulated mechanisms etc.).

It is worth mentioning that current mathematical platforms such as *Mathematica*, *MatLab*, *Maple* etc. provides tools to make and control of geometric constructions, similar to those described above. These softwares are characterized by a high degree of generality and are not free.

Also, current CAD platforms offer an impressive array of highly performing tools for geometric modelling of reality, [3], [4]. The proper use of these tools and the imposition of the necessary constraints, allows for the modeling and kinetostatic analysis of the mechanisms.

3. CASE STUDIES

The case studies presented below are intended to highlight the applicability of interactive geometric software in mechanical engineering. These studies were generated in GeoGebra, [5] and do not reveal the full applicability in mechanical engineering of this software.

Case studies are as follows:

- Viewing plane stress.
- Axial forces in the bars of a lattice beam.
- Viewing plane stress
Figure 6 presents a GeoGebra image capture showing a certain position of the stresses computation directions in the vicinity of an infinitesimal volume element which is in a plane stress state.

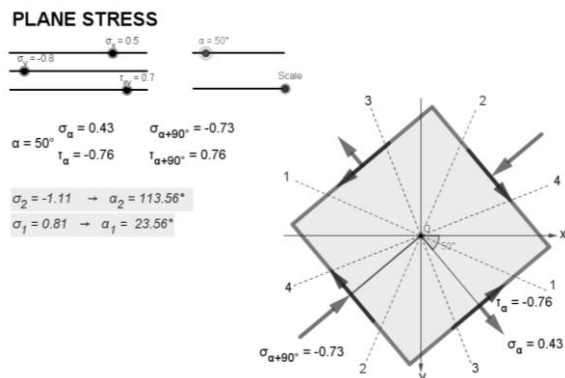


Fig. 6 Viewing plane stress and their properties

The application provides the student following controls:

- Control of the values of the stress tensor components (sliders σ_x , σ_y and τ_{xy}).
- Position control of the computation directions of the stresses (slider α).
- Control of the graphic representation size (slider *Scale*).

The application displays the value of the main stresses, the main directions and the maximum shear stresses directions. Also, the values of the angles corresponding to the main directions are displayed.

The manual or automatic control of the sliders allows making suggestive animations about the plane stress state.

- Axial forces in the bars of a lattice beam

Figure 7 presents a GeoGebra 5 image capture showing a lattice beam loaded with a force system.

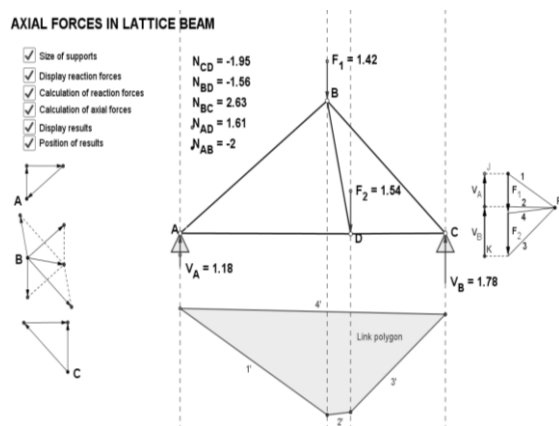


Fig. 7 Lattice beam loaded with a force system

The application allows control of the value of the loading forces. Also, the size of the supports can be

controlled. The application is also an example of the use of checkboxes, which controls the display of the search results (reaction forces, axial forces) and graphic constructions that determine the value of the axial forces and can be used to verify students' knowledge.

Thus, by inhibiting, for example, displaying graphical solution of the problem and axial forces values, one can verify the student's ability to solve the problem.

The application can be extended to lattice beams with more complicated geometry.

8. CONCLUSION

Interactive geometric software, through capabilities made available to the user, have important and interesting uses in mechanical engineering, which is under-explored and under-used at present.

Graphic views and graphical methods implemented in interactive geometric environments combine in a happy way the advantages of graphical methods and the advantages of precision of numerical calculations made with the electronic computer.

Graphic-analytical methods, so useful in forming, training and developing engineering thinking, can be used with a real success if they are "transferred" into the virtual environment of interactive geometric software.

The upward dynamics of interactive geometric software development will bring in the near future new tools for training and development of the engineering thinking.

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