

ASPECTS OF GRAPHICAL METHODS WITH THE USE OF CAD INSTRUMENTS

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Abstract: The programs that are specialized in computer-assisted graphics can be used to study some theoretical didactic matters, to the double concern of the teacher, and the double advantage of the student: the understanding of the fundamental phenomenon that is being studied and the acquiring of some basic programming skills. The present article illustrates a few examples of using software packs in the study of some theoretical problems by means of graphical methods: intersections, plane – parallel motion, animation.

Key words: CAD, AutoLISP, AutoCAD, Macromedia Flash, SolidWorks frame, keyframe.

1. GRAPHICAL METHODS

There was a time when the graphical methods were irreplaceable. Once one of my students asked me why in descriptive geometry there is this convention to represent a point as a small, empty circle. I explained to him that this practice has been handed down since the days when the drawer used to apply the graphical method of determination, in order to easily identify in the drawing board the compass hole, which, most of the times, was a rotation center to be used again, and therefore was marked with such a small empty circle. The following were determined by means of graphical methods: the rod curves, the motion, speed and acceleration values of the mechanisms with joint bars or with cams, the values of the coordinates of some significant points, the projections of some curves or the intersection polygons among geometrical figures etc.

The emergence of the electronic methods of calculation has led to the replacement of the graphical methods with the analytical ones, which are faster and, evidently, more accurate. However, by using a computer equipped with a specialized graphics program, just by considering that any graphics software relates its coordinates to any point on the screen, in

some cases the graphical methods can be reconsidered, regaining the necessary precision. Here is, for example, the intersection of a line with a sphere.

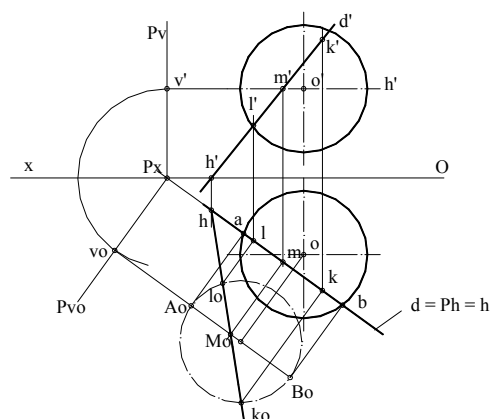


Fig. 1 The intersection of a line with a sphere

Figure 1 shows the intersection as represented in double orthogonal projection with the help of AutoCAD. The program returns the coordinates of points L(l, l') and K(k, k') which, if the necessary translation corresponding to the chosen reference system is made, are actually the solutions of the system

$$\begin{cases} (x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 - R^2 = 0 \\ \frac{x - x_a}{x_b - x_a} = \frac{y - y_a}{y_b - y_a} = \frac{z - z_a}{z_b - z_a} \end{cases}$$

1.1. Graphical method to determine the cinematic sizes of the driven element in a rod mechanism

Given the rod mechanism in figure 2, the vector relations, for example of the instantaneous speeds of its elements, are known.

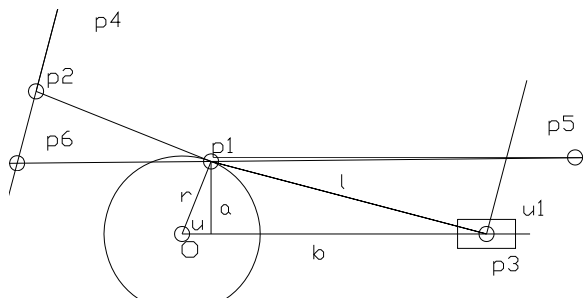


Fig. 2 Rod mechanism

The vector V_{p1} is known both in direction and in module, while V_{p3} and V_{p3p1} are known only in direction. It is on these observations that the so-called “plane of the speeds” construction is based, which has tormented generations of students in the theory of mechanisms.

$$V_{p3} = V_{p1} + V_{p3p1} \quad (1)$$

This construction can be automated with the help of an AutoLISP application, which requires manual introduction of the mechanism’s geometrical values, as well as the instantaneous value of the ray-angle, here marked with “u”. In the following application, called “bbiela”, a ray of 100 units, a rod of the length of 200 units, a revolution of the leading element of 800 revolutions per minute, and a frequentative sequence of 10 units, with a 36-degree per sequence increase of the variable were chosen for exemplification.

```
(DEFUN C:bbiela ( )
  (setq x1 (list 0.0 150.0))
  (setq x2 (list 420.0 150.0))
  (setq y1 (list 210 0))
  (setq y2 (list 210 300)); axele carteziene de
  coordonate
  (Command "xline" x1 x2 "")
  (Command "xline" y1 y2 "")
  (Setq o (inters x1 x2 y1 y2 nil))
  (Command "Point" o)
  (SETQ r (GETDIST "Valoarea razei r:"))
  n (GETREAL "Valoarea turatiei:")
  l (GETDIST "Lungimea bielei l:")
  (SETQ u 0)
```

```
(repeat 10
  (setq u (+ 36 u))
  (setq p1 (polar o u r))
  (setq p2 (polar p1 (+(/ pi 2) u) ((* pi 2 r n)
  1000)))
  (setq a (* r (sin u)))
  (setq b (sqrt (- (expt l 2) (expt a 2))))
  (setq c (* r (cos u)))
  (setq p3 (polar o 0 (+ b c)))
  (setq u1 (- (angle p1 p3) (/ pi 2)))
  (setq p4 (polar p2 u1 100))
  (setq p5 (polar p1 0 200))
  (setq p6 (inters p1 p5 p2 p4 nil))
  (Command "Point" p1)
  (Command "Point" p6)
  (Command "Point" p3)
  (Command "circle" o r)
  (Command "pline" p1 p3 "c")
  (Command "pline" o p1 "c")
  (Command "pline" p1 "w" "1" "1" p6 "c")
  ))
```

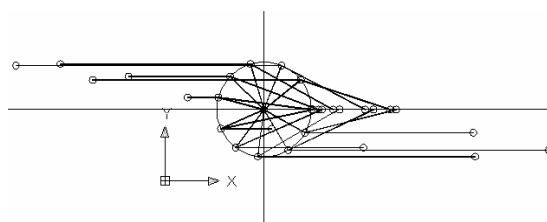


Fig. 3 The instantaneous values of the driven element’s speed in the 10 selected positions

For each selected position, the program returns the instantaneous value of the driven element’s speed, by introducing! (distance p1 p6) in the application with an accuracy comparable to that of any other numeric program (fig. 3).

1.2. Animated representation

It is well known that, to make an animated representation of the functioning of a cinematic scheme, any specialized environment requires the successive insertion of the positions occupied by the moving elements (for instance, in Macromedia Flash, frame, keyframe). Yet, these programs do not offer the possibility to accurately introduce the geometrical values, which is why it is imperative to use a specialized geometric modeler, such as AutoCAD.

The next application, called “abiela”, serves the purpose to automatically represent

the positions of the mechanism's elements based on the current value of the angle "u".

```
(DEFUN C:abiela ( )
  (SETQ o (list 400 600)
    r 100
    l 200
    u (GETANGLE "Valoarea unghiului u:"))
  (SETQ p1 (polar o u r)
    a (* r (sin u))
    b (sqrt (- (expt l 2) (expt a 2)))
    c (* r (cos u))
    p3 (polar o 0 (+ b c)))
  (Command "Point" p1)
  (Command "Point" o)
  (Command "Point" p3)
  (Command "pline" p1 p3 "c")
  (Command "pline" o p1 "c"))
```

In this way, the insertion of the successive frames is possible, for example with the use of Macromedia Flash (fig. 4, fig. 5).

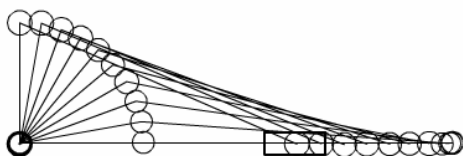


Fig. 4 Animated representation of the functioning of a mechanism for a 90-degree angle

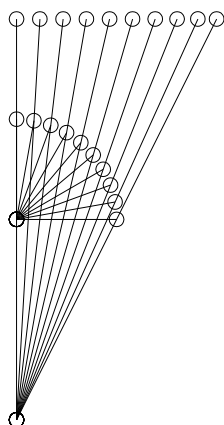


Fig. 5 Analog animated representation of the functioning of a culisse mechanism for a 90-degree angle

1.3. Solid Modeling

The drawing, the modeling, the making of the calculations necessary for the projection,

as well as the parametrical representation of some classes of figures with identical geometrical forms, but with different dimensions, can all be obtained with the help of the software packs CAD, i.e. the application programs that facilitate engineering-type functions in the process of conceiving a product.

These programs are instruments that can be used to generate and manipulate elementary geometrical forms or that can be improved to the superior level of a system's analysis or functional optimization. But all these cases originate in the geometrical characteristics of the analyzed system, in its representation, in the representation of the mechanical assembly or of the architecture, the electrical circuit, the map, etc. Therefore, it can be said that, at the lowest level of the programming activity, the theoretical basis of a program specialized in plane representations is the theory of the projection systems, the reference systems, the coordinates systems, etc.

A CAD system can be characterized by three elements, all present within a program: the instruments for Computer Assisted Drawing, the possibility for the operator to intervene by means of the programmable interface in the cases of parametrical representations, and the Geometric Modeling instruments. In the synthesis stage, sketches and general drawings are made, constructive solutions are adopted, and work drawings containing all the explanations for the technological process are created. Next comes the stage of analyzing the model and its functioning, by observing the ways in which the project can be optimized. The most performant computerized techniques elaborate the virtual simulation of the model's functioning with great accuracy, a very useful effort in the experimenting of the virtual prototype, phase called virtual prototyping.

Albert Kalman, in his article entitled "Why 3D modeling", states: "it is estimated that in the last decade, around 100.000 of designers from all over the world have changed their way of approaching the designing process, by moving from 2D design systems to 3D design, and using solid modeling programs. Some specialists estimate that only after 2000, the

3D modeling software currently on the market and destined to the wide range of users, will reach a full natural growth.” Well, this reality already exists.

1.3.1. Specialized Programs for Computer Assisted Graphics

Computer - assisted design and drawing are made with the help of the computer programs which generally can be grouped into the following categories of IT applications:

1. Applications for computer - assisted geometrical modeling and drawing, of which the most popular are AutoCAD, Turbocad, KeyCAD, Design CAD, Solid Works;
2. Applications for solving general problems of mathematical calculation, useful especially in the CAE – assisted engineering (of which the most spread are Matlab, Mathematica, MathCAD, Maple, etc.) or in the simulation of some particular systems described by ordinary differential equations (such as Spice, for the analysis of the electronic circuits, EMTP, for the analysis the electro-energetic networks);
3. Applications specific to a particular field, like PipeCAD for the design of installations, AeroCAD for the design of aeronautical constructions, ArhiCAD for architectural designs, GIS CAD for topography and map making or other topometrical documents based on “Geografic Integrated System”. Other examples include Cadence, Mentor, Microcad, Orcad, specialized in electronic design, which form a distinct branch, called “Electronic Design Automation”;
4. Applications destined to numeric modeling, with the method of the finite element or with the help of some similar functions used to solve equations with partial derivatives that appear in assisted design, such as those of structural calculation ANSYS, COSMOS, NASTRAN. Other examples include those used in the modeling of the fluid flowing, environments heating, electromagnetic field evaluation, diffusion of the electric charge carriers and, more recently, for interdisciplinary problems, called “multyphisics”;
5. Finally, the systems with a maximum degree of integration, reuniting CAE, CAD

and CAM components, such as I-DEAS, CATIA, EUCLID, ProEngineer or SAAP.

Following this general enumeration, we would like to add another significant aspect, which shows the extent and importance of these activities and researches: in the USA only, the CAD, CAM and CAE industry has generated a software products market and software - associated services, with applications only in the mechanical field, of more than 5.5 billion dollars worth in 2000 only.

1.3.2. Solid Modeling

This is the most complex form of modeling, with manifold advantages. A real, photographic image of a model is obtained, which implicitly represents the database necessary for analyses and simulations (CAE) or even for processing (CAM).

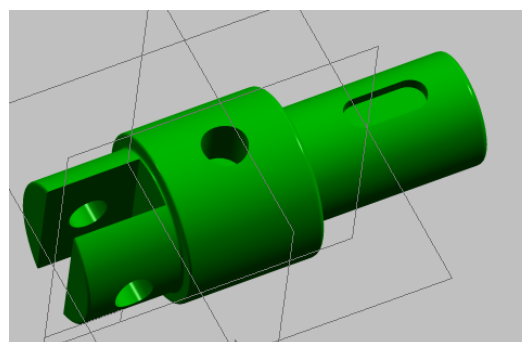


Fig. 6 Shaft modeled with Solid Edge

Solid modeling offers not only a better visualization of the model, by allowing the model to be observed from any point in space (the vpoints variation), but also the possibility to automatically obtain its orthogonal projections (Monge).

Figure 7 illustrates two orthogonal projections and one section (the work drawing) of the solid model in figure 6, automatically obtained with Solid Edge.

For comparison reasons, figure 8 illustrates the image of the same shaft, modeled with Solid Works, in 4 “viewports”, with three orthogonal views and an axonometrical one.

Another example is illustrated by the polyhedron modeled in figure 9, with the use of the “protrusion” instrument of the Solid

Edge program. Starting this year, two of the four program's modules can be used in the Air Force Academy in Brasov: Solid Edge Part and Solid Edge Draft.

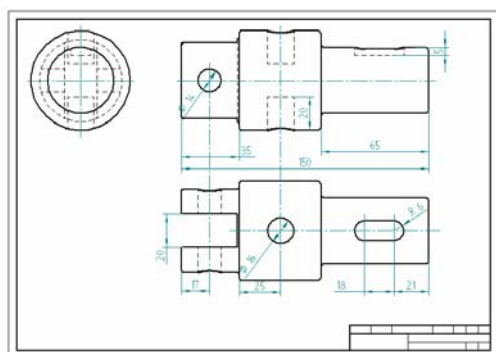


Fig. 7 Orthogonal projections of the shaft

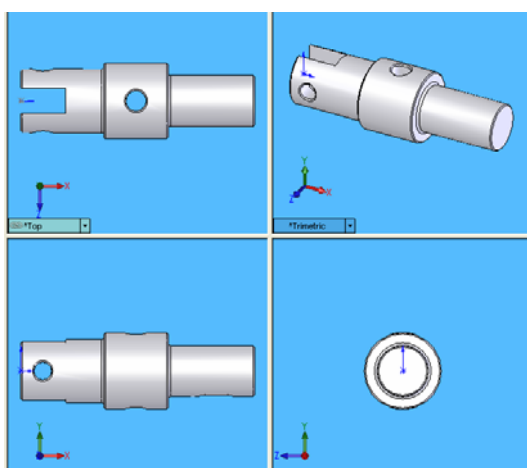


Fig. 8 Same shaft, modeled with Solid Works

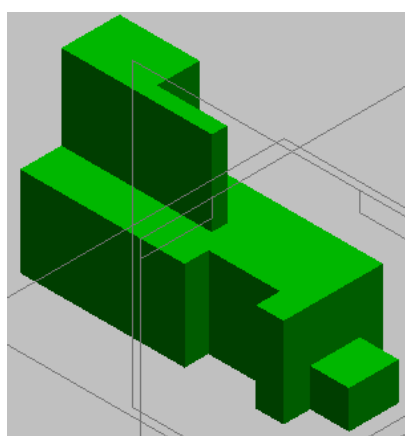


Fig. 9 Solid model of a figure – prisms combination

Finally, figure 10 represents the orthogonal projections (Monge) of this solid, automatically obtained with Solid Edge.

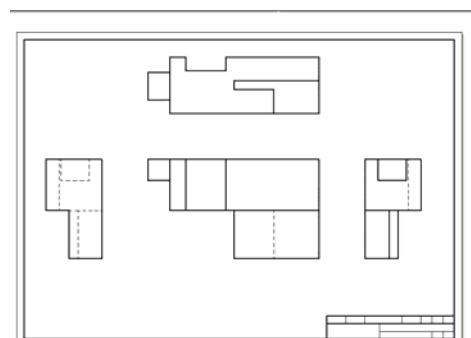


Fig. 10 The orthogonal projections of the polyhedron in figure 5

1.3.3. Visualizing 3D curves with the use of solid modeling

This CAD instrument can be used in an efficient and suggestive way in order to model and visualize three-dimensionally some curves in space, obtained as an intersection of solids, cylinder-conical or revolution figures, whose analytical forms and properties are studied by the students in their first year, as part of the descriptive geometry course. This approach familiarizes them with its generating method, fosters the abilities to use this modern instrument and, eventually, offers them the satisfaction of 3D visualizing, undoubtedly more captivating and suggestive.

The examples that illustrate this fact are manifold. The one I've chosen is, seemingly, humorous and commonplace, but which covers a lot of geometry: the modeling of a sphericon (fig. 11).

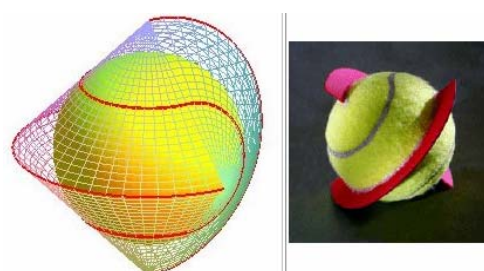


Fig. 11 Couture de balle de tennis

On the webpage:

<http://www.mathcurve.com/courbes3d/couture/couture.shtml>, Alain Esculier demonstrates how the properties of the curve upon which the tennis ball is sewn, cause this curve to be the tangent curve of a sphericon with a sphere inside.

One can obtain a sphericon by using a 90-degree double cone, cross sectioned at the top by a plane passing through the rotation axis, and reattaching the sectioned parts after a 90-degree turn. The procedure was performed with the use of the “assemblies” mode of Solid Works (fig. 12 and fig. 13).

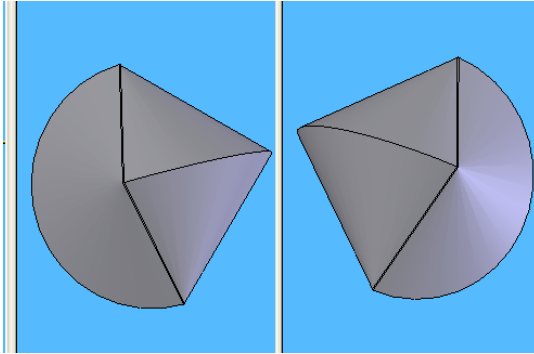


Fig. 12 Solid Works - modeled sphericon

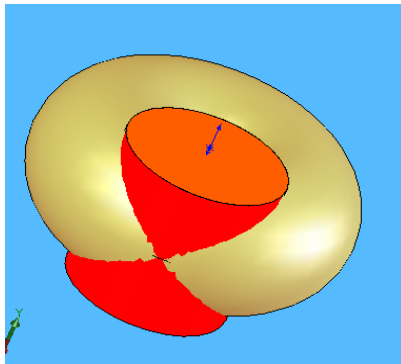


Fig. 13 Assembling of a 3D model

A second example is represented in figure 14, which illustrates the 3D modeling of the Archytas curve, as the intersection of a void-holed torus with a cylinder of parallel axis to the torus axis.

The program offers the possibility to change the imaginary point from which an object is viewed and this is the main advantage

of 3-D representations over those axonometric, in the case of which, once the axonometric plan was selected, it can no longer be changed.

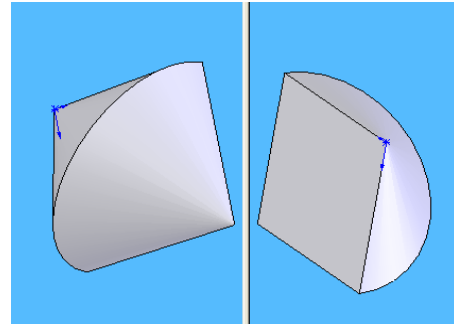


Fig. 14 Archytas curve

Finally, fig. 15 illustrates the dome image of the maritime museum in Osaka (architect P. Andreu), which uses as an architectural solution an envelopment of the Viviani curves (intersections of sphere and cylinder).



Fig 15 The maritime museum in Osaka

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