Kinematic and analytical Surfaces Programming for Solution of Architectural Designing Tasks

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Abstract

A number of relatively simple programs which can be used as supplement to Autocad R14 are developed. They make it possible to model various kinematic surfaces and employ them in architectural designing. Algorithms of complex shape surfaces forming are synthesized and examples of their construction are given. The key words are: kinematic surfaces, analytical surfaces, 3D modelling, computer graphics, AutoLisp.

1. INTRODUCTION

The potentials of civil engineering nowadays result in erection of great complexity constructions. In this respect the architect's intentions are in fact unlimited and he can create any expressive architectural forms. However, surfaces having simple shapes are normally used in the course of elaboration. A great variety of known surfaces, including those found in nature, are left with no attention. Partly, it is due to the difficulties connected with their design, visual presentation and engineering computation.

The most effective way available for modelling surfaces is a computer simulation. But the general- purpose packages when their basic versions are taken don't possess sufficient capabilities to construct complex surfaces; specialized supplements and program products, being expensive, didn't gain popularity. The AutoCAD package which is the most common one in the Russian market has the same disadvantages as the above-mentioned general-purpose software packages. Nevertheless, the open architecture of the package gave the authors opportunity to create relatively simple programs in the Autolisp language, realizing the functions of surfaces modelling, unavailable in the basic version package.

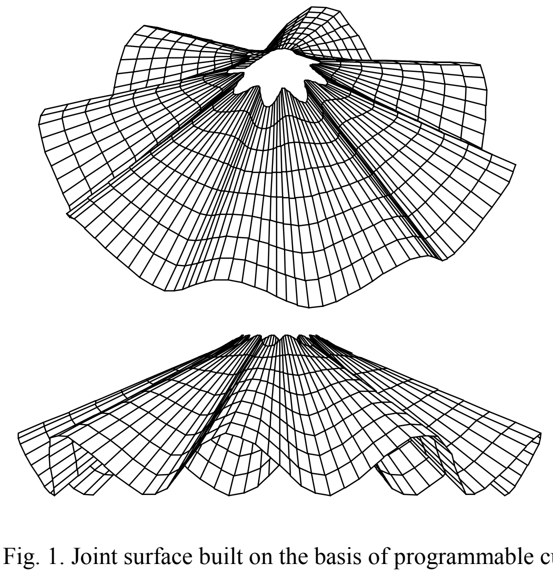

Fig. 1. Joint surface built on the basis of programmable curves

2. CREATION ALGORITHMS OF KINEMATIC SURFACES AND THEIR EXAMPLES

The following program modules assisting in realization of architect's intentions are developed.

1. Space curves of complex shape e.g. spiral of an arbitrary profile, sinusoid on the cone surface and on that of sphere or torus.
2. Surfaces with one guide the generatrix of which may be of an arbitrary space profile, being scaled and rotated in the course of displacement (in particular, tunnel and tors surfaces, surfaces with the plane of parallelism).
3. Surfaces where two guides and a generatrix of an arbitrary shape, deformed while connecting the guides according to various algorithms, are joined.
4. Surfaces of rotation having the generatrix of some specified shape, e.g. arc of a circle, which slides along two-three guides and undergoes appropriate deformation.

The curves programmed are used as guides and generatrix. The universal algorithm of construction makes it possible to get spiral of an arbitrary profile where the spiral turns follow the shape of a specified curve. While applying programmable curves one can create standard surfaces of more complex shapes that will lead to the extention of modelling potentials by standard means. Fig. 1 shows linear joint surface the guides of which are sinusoids built on the cone surface.

The tors surfaces possess a number of technological advantages. Fig. 2 presents the tors surface the guide of which was constructed as a spiral comprised within the specified profile. The desirable spiral profile is first plotted on the screen. Surfaces 1 and 2 are built using the first two program modules.

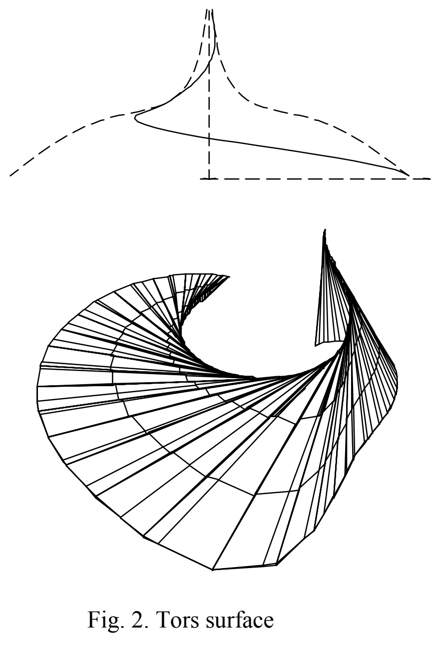

Fig. 2. Tors surface

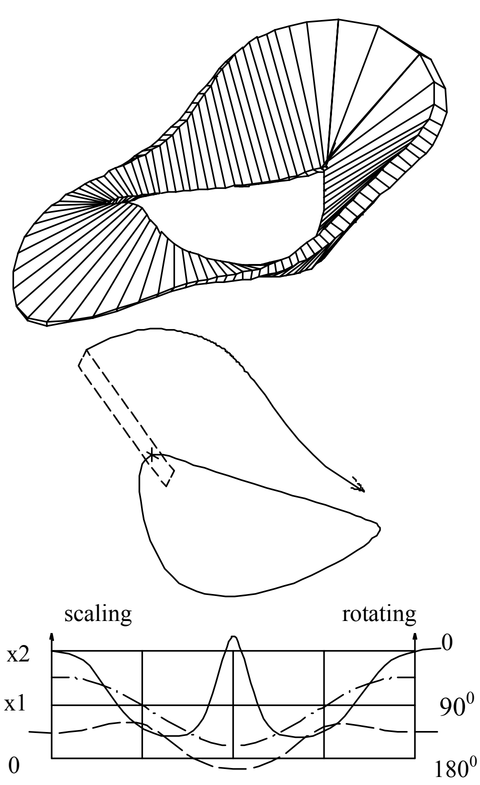

Fig. 3. Tunnel surface

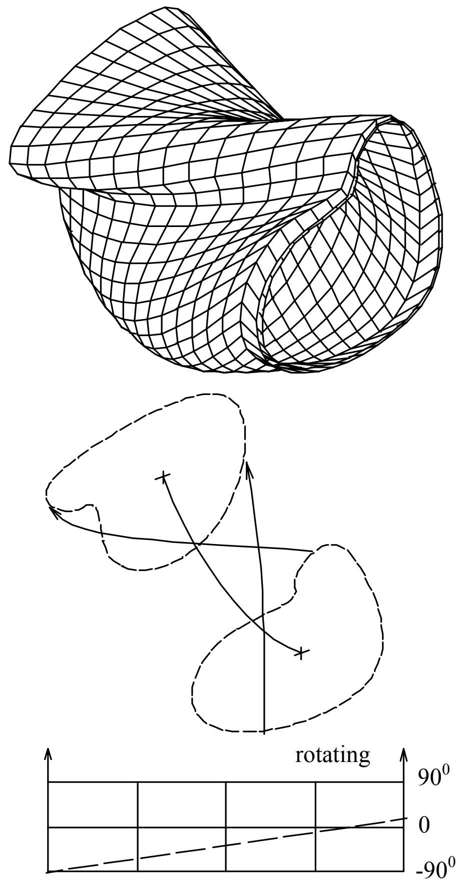

Fig. 4. “Turbosoma”

Tunnel surfaces can successfully be applied to design irregular space shells. Fig. 3 shows the tunnel surface produced by the rectangle in it’s movement along the space guide (the latter is presented by the line of the cylinder-cone intersection). While moving the rectangle is being rotated relative to the guide tangent and scaled in two directions. The transformation of the spiral profile is preset by the user as a series of graphs he draws on the screen beforehand.

Fig. 4 is a reproduction of the turbosoma surface (one of the surfaces of architectural bionics). The surface is constructed using module 2 as a transfer surface along the specified guide, with the plane of parallelism and even rotation of the profile drawn in advance on the screen.

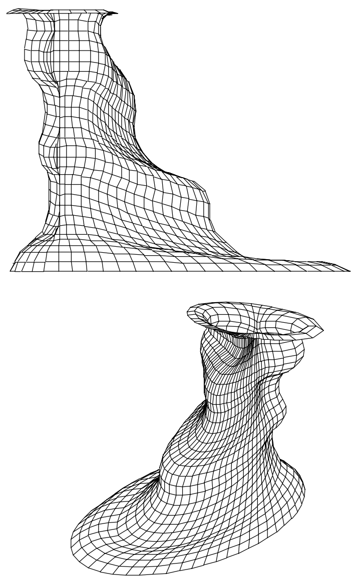

Fig. 5. Surface of joint with two guides and a generatrix of an arbitrary shape

The surfaces of the arbitrary generatrix joint, module 3, allow to create novel surfaces of architecture. Fig. 5 displays the surface the guide of which is presented by two ellipses. The generatrix has a wave-like profile, being rotated and scaled in accordance with the current distance between the joint points.

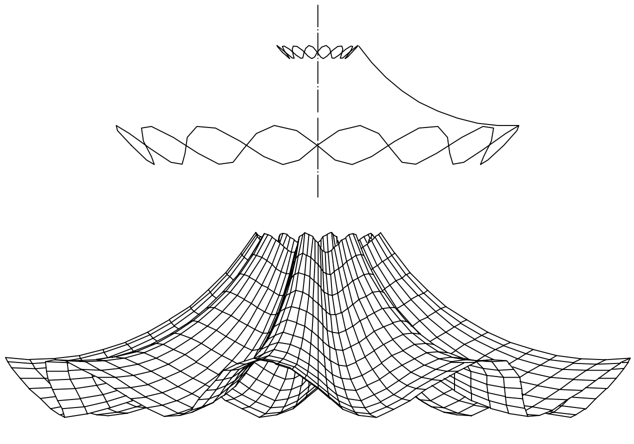

Fig. 6. Rotation surface of regular shape

While using module 4 forming the rotation surfaces the great potential of shape creation is revealed. These include both regular (Fig.6) and irregular (Fig.7) surfaces, the surface of joint with the generatrix having the shape of the arc of a circle in the rotating plane (Fig. 8).

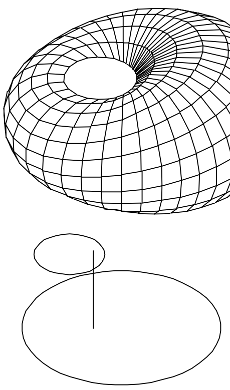

Fig. 7. Rotation surface of an irregular shape

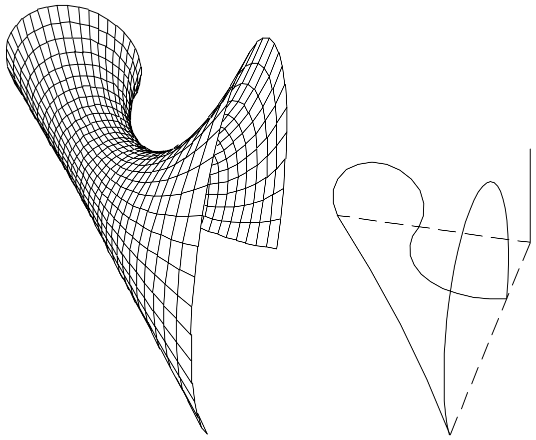

Fig. 8. Rotation surface, the generatrix being in the rotating plane

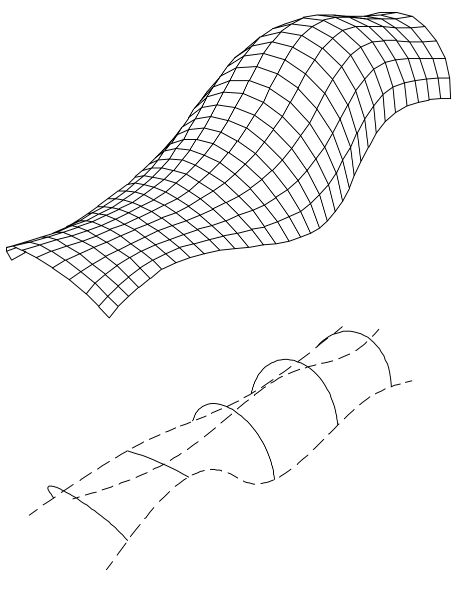

Fig. 9. Surface of parallel transfer of the profile deformed

The rotation axis removed, the surface of parallel transfer of the profile deformed is realized (the arc built with 3 points), (Fig. 9).

Availability of complex shape creation using the modules developed substantially increases the effectiveness of sketch design. The programs considered are included in the academic course named "Computer simulation" for the students of "Architectural-Constructional" faculty., who specialize in architecture. The work to possibly integrate the results of geometric modelling into the subsequent stages of engineering design is being conducted.

3. ANALYTICAL SURFACES

Alongside with kinematic representation of surfaces there is a facility to analytically describe them by means of mathematical formulae. Though the general behaviour of complex mathematical functions can be predicted, while creating surfaces on their bases one may come across some unpredictable element. When there is an infinite number of variations of functions themselves it is interesting to search for the most expressive surfaces from the viewpoint of aesthetic. The way such surfaces are created doesn't diminish their value; on the contrary, complex analytical surfaces have the right to be used as elements of design and treated as pieces of art. An image-bearing analytical surface is a rare case of harmony of rational and artistic principles.

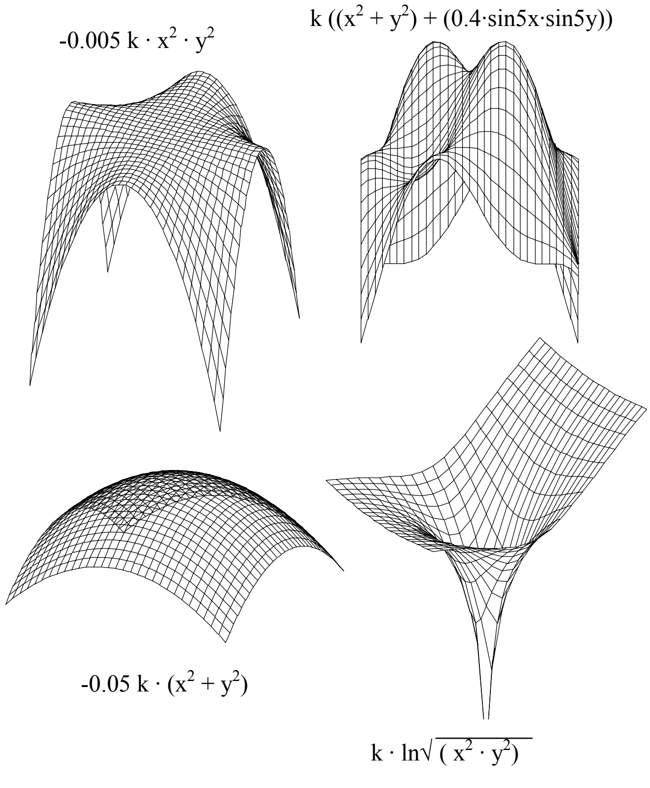

Fig. 10. Surfaces created on the basis of quadratic functions combination and that of different functions

3.1 Examples of Creation of the Analytically Preassigned Surfaces

Strict regularity of mathematical formulae is manifested by expressive images of architectural shapes. Within the infinite variety of possible analytical surfaces the most laconic of them are of interest. For instance, combination of quadratic functions produces different forms of arch constructions (Fig. 10);

combination of different functions with one another is the source of still more original solutions.

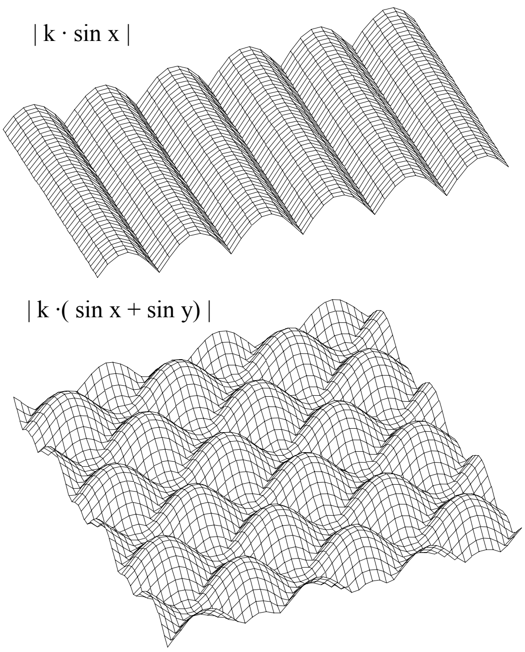

Fig. 11. Surfaces created on the basis of periodic functions combination

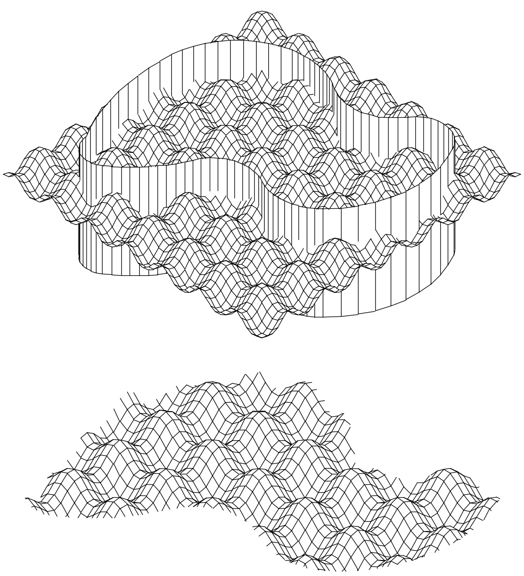

Fig. 12. Surface obtained with the help of the boolean “intersection” of an analytical surface limited by an arbitrary contour

3.2 Examples of Creation of Surfaces Specified with the Help of Periodic Functions

Due to combination of periodic sine and cosine functions different folded and cell structures (Fig. 11) are produced.

3.3 Formation of the Surface Limited by an Arbitrary Contour

If an arbitrary closed curve, circle or ellipse are specified as limits for a periodic function, then ‘the section” of such a surface in the plan and along the section contour will be presented by a live uneven curve. In practice it may be realized through the boolean operation of “intersection” of two objects – the surface of periodic function and the solid of extrusion of a closed curvilinear profile (Fig. 12).

4. CONCLUSION

Availability of complex shape creation by means of modules worked out considerably enhances effectiveness of sketch design. The programs described are included in the academic plan as “Computer Simulation” course for the students of “Architectural-Constructional” faculty, specializing in architecture. The work on combining the results of geometric modelling with the subsequent stages of engineering design is under way.

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