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Achievements of the Ukrainian School of Applied Geometry[1]

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Abstract. This is a brief summary of recent scientific activities in Ukraine in the field of Applied Geometry.

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1. Introduction

The *Ukrainian School of Applied Geometry* was founded by Professor S.M. Kolotov (1880–1965) who taught and prepared 32 Ph.Ds. He was the author of the method of transformation of projections by the way of an auxiliary rectangular and oblique-angled projection.

The distinctive features of the Ukrainian scientists' works consist in applications of the methods of Applied Geometry for the solution of practical problems in various areas of science and engineering. The geometric modeling of objects, processes and phenomena has been carried out with the purpose of their optimization.

2. Different schools of Applied Geometry in Ukraine

2.1. Kyiv National University of Building and Architecture

The majority of problems solved at the Kyiv National University of Building and Architecture refer to construction and architecture.

So the author and his disciples investigated the problem of *architectural envelopes*, carried out a geometric analysis and gave the geometric interpretation of main conditions and requests for their design. As the prototype of architectural covers we analyzed the geometric form of some surfaces of natural origin with the purpose to determine the principles which can be used

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in architectural analogues. The two problems at the geometric design of surfaces composed from curved or planar patches were formulated:

- The primal problem consists in breaking the surface into patches by the way of exact and approximate parqueting.
- The inverse problem consists in the creation of surfaces out of portions of beforehand given surfaces.

Many disciples of the author dedicated their theses to the geometric modeling of thin-walled covers. A number of optimization problems of designing awning, guy and pneumatic constructions both of low and high pressure were solved. Some researches are dedicated to constructions under transformation. Three theses are dedicated to the optimization of the form of a cutting machine tool used for the destruction of rocks. One work is dedicated to laying-out fabrics in tanning industry, the other to forecasting landslides. Two more works are dedicated to the visual perception of environment.

As a new speciality *'Technical Aesthetics'* was introduced; there were defended two theses: one doctoral thesis was dedicated to geometric principles of artistic design; another Ph.D. thesis addressed problems of geometry and semiotics of aesthetic self-descriptiveness.

Altogether 63 Ph.D. theses and 7 doctoral theses were defended under the direction and supervision of the author.

Professor O.L. Podgorny directed the researches in three interlinked directions:

- The first area of research is dedicated to the development of the *theory of images*. The researches related to this direction are dedicated to the construction in plafond perspective and to geometric methods for the analysis of its perception as well as to the examination of general cases of the system with two images and their generalization to auxiliary projections with spiral and broken lines.
- The second area of research is dedicated to the *geometric modeling of spatial structures in architecture and technique*. The researches in this area were generalized in the doctoral thesis of Prof. Podgorny. This thesis is mainly dedicated to the design of architectural envelopes. One basis of these researches is a method for specifying within the multitude of lines a family of lines forming a surface. As the elements of the multitude were considered not only curves and straight lines but so-called generalized broken lines as well.
- The third area of the research is dedicated to *geometrical modeling of phenomena and processes in architectural and constructional physics*. In particular the geometrical modeling of sound and light proliferation in architectural environment and associated tasks in the architectural and constructional physics were considered.

Prof. Podgorny has trained 42 Ph.Ds and 4 Doctors of Science. Prof. S.N. Kovalev and Prof. K.A. Sazonov successfully work with post-graduates. Prof. Kovalev has trained 22 Ph.Ds.

2.2. National Technical University (KPI)

The 'Descriptive Geometry, Engineering and Computer Graphics Department' at the National Technical University (KPI) has 6 Doctors and 19 Ph.Ds. The basic trend of research of this scientific school is the development of *methods for geometrical modeling of objects, processes and phenomena*.

The founder and manager of this scientific school is Prof. Pavlov, who trained 30 Ph.Ds and 7 Doctors of Science. The research is carried out primarily in three areas:

- Under the 'Aviation Industry Information Technology Program' the development of methods for the geometric modeling of *lines and surfaces for aircrafts* and the geometric modeling of technological processes for *automated systems for production*.
- Development of methods for modeling *phenomena of nature, physical and technological processes*, technical systems including the methods of multidimensional descriptive geometry.
- Development of methods for modeling technological processes of *soil treatment* with the purpose of constructing *agricultural instruments* and improving the technology of their production and implementation.

In Prof. V.S. Obukhova's doctoral thesis (National Agrarian University) nonlinear projections were applied to line congruences of first order as well as to a number of straight lines. This led to a group of nonlinear models of higher order. A method of incidences in dual representation has also been developed. On the basis of intersecting given subsets of multitudes (straight lines, curved lines, surfaces) ruled surfaces of third and fourth order were obtained and investigated. Also methods of nonlinear transformation were developed. Practical utilization of the created surfaces was demonstrated at samples of working tools for agricultural machines, at the design of products with curvilinear forms, and the development of cutters with variable geometry, attaining riffling surfaces, etc.

In 9 defended Ph.Ds and 1 doctoral theses Obukhova's students treated ideas of their teacher.

2.3. Tavria State Agro-Technical Academy

The 'Melitopol School of Applied Geometry' currently based at the Tavria State Agro-Technical Academy was founded thanks to efforts of Prof. M.M. Yuditskyj and promoted under his student Prof. V.M. Nidysh. For over 15 years the scientific group has been working on the subject "Modeling Phenomena and Processes in the Agricultural Complex".

The main direction of this research is the *discrete geometrical modeling*. Its components are the discrete interpolation, discrete differentiation and integration of discretely represented data output of any phenomenon or process. In this area quite prominent results have been achieved during the last 10 years.

There were defended 3 doctoral and 5 Ph.D. theses and 4 more papers are to expect in the nearest future.

The main objective of this research is the improvement of effectiveness and precision of modeling, the preservation of energy, time and human resources. The developed methods were implemented at the Avtozaz-Daewoo Plant (Zaporizhia), Yuzhmash Plant (Dnepropetrovsk), Malyshev Plant (Kharkiv), Azovstal (Mariupol), AvtoZAZ-Motor (Melitopol) and others. The solved tasks contribute to the mathematical processing of empirical results, to discrete surface modeling in auto-building industry, forecasting and potential of production.

2.4. Odessa Region School of Geometry

The main objective of research under the supervision of Prof. Podkorytov at the Odessa region school of geometry is entitled *"Theoretical methods for the automated production of corresponding non-interfering quasi-spiral surfaces"*. Within this research a theoretical basis has been given for the development of geometrical, mathematical and analogue models of corresponding quasi-spiral surfaces operating without distortion of engagement. The invariant method of multi-task cutters with dimensional cutting edge was first developed, as

well as a kinematic method for generating quasi-spiral surfaces with their application in tool production.

On the basis of PODKORYTOV's theorem on roll-sliding axoids a principally new invariant method has been disclosed for exterminating interferences at quasi-spiral surfaces. A formalized process for the geometrical modeling of quasi-spiral surfaces allows to exterminate incongruences with the use of powerful seventh generation computers. The implementation of the designed cutting instruments and spiral engagements allows to avoid any malfunctions of cutting, jamming and the dangerous concentration of strains during the production for a wide range or machine building details including cutting tools. Due to a complex automatization the technological production process of these complicated forms is adequate to today's technical requirements.

Prof. PODKORYTOV trained 9 Ph.Ds and 1 Doctor.

2.5. The Kharkiv School

As subject of research of Prof. KUTSENKO, the leader of the Kharkiv school, an array of tasks was selected. The solution of these tasks becomes much simplified via using a basic method in descriptive geometry and reflections on projections.

Indeed, the experience in developing algorithmic solutions for applied tasks disclosed that for the process of achieving expected results it would be useful to consider the *'internal' projecting nature* of these tasks. Therefore the solution of the primary task often consists in achieving calculations pertaining to the creation of a layout (i.e. projection) by means of computer graphics. In this respect the research of the Kharkiv school of geometry is developing in three directions:

- In the first one a projecting method is developed for the calculation of special integrals in radial energy transmittal in space from one surface to another. The projection method used during integration allows refraining from the traditional "pacing" over surfaces.
- The second direction is associated with the development of a projection method for the identification of enveloping parametric families.
- The third direction treats the development of a projection method for geometrical modeling of parallel multitudes with the possibility of calculating their integral characteristics.

Prof. KUTSENKO has trained 12 Ph.Ds.

2.6. The Donetsk School

The Donetsk School is headed by Prof. I.A. SKIDAN. Its research uncovers issues pertaining to the applied *theory of analytical form-creation* based on the global parametric process. The theory generalizes the analytical interpretation of basic constructive methods for projecting structures and for building complicated forms, e.g., kinematics, disclosing a linear frame of surfaces from line congruences, special parametric modeling of space, transformations, partial-analytical modeling.

The theory is oriented for using computer technologies at the project implementation and it covers the majority of surface categories along with global parametric processes as well as the whole spectrum of projecting requirements for surfaces intrinsic to certain constructional methods.

Prof. I.A. SKIDAN has trained 6 Ph.Ds.

2.7. A final example of Applied Geometry problems

One of the areas for an effective application of methods in Applied Geometry is the *recognition of forms from images*. The correspondent research was carried out in Ukraine from the beginning of the nineties within the frames created by the Ukrainian school of Applied Geometry. It deals with a concept of a geometry of invariants in the multidimensional space of information characteristic of images — measurement-free combinations of seven invariant functions of brightness (Prof. V.M. Korchynskyj, Dnepropetrovsk National University).

A number of these characteristics has the structure of a linear space and it provides identical relations between points in the space of the model and functions of brightness of the object. An increase in measurement characteristics of this space allows to consider smaller details of geometrical forms. A number of points (vectors) received from a fixed object under different positioning and projecting conditions develops a multidimensional view; its geometric interpretation is defined by the metric of this space. In particular, in the affine correspondence between the points of an object and their image the above-mentioned variety represents the absolute quadric (pseudosphere in pseudo-Euclidean metrization of the model space); in the projective correspondence between images obtained under different perspectives this surface is cubic, etc. In fact, the identification and analysis of images is related to a series of positional and metrical tasks of Applied Geometry in the model space.

The results obtained in these researches were assumed as a basis of integral information technology for the interpretation of images with projective nature. In particular this technology is used for the automated analysis of photogrammetric images received from satellites.

3. Conclusion

All aforesaid testifies to the fact that scientific research of Ukrainian scientists and teachers covers a wide range of problems of geometric modeling of objects, processes and phenomena. As a rule, the results of Ph.D. and doctoral theses have been applied at different design institutions, research organizations and in industry. Apart from scientific articles and monographs, new results have also certified with Ukrainian certificates of authorship and patents.

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