Geometric modeling laboratory as an engineering infrastructure in the digital economy

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Abstract. The paper is devoted to the questions of creating a geometric modeling laboratory, which can decide many project problems as engineering infrastructure. Actuality of this problem for Uzbekistan is justified by statistical data about using research and development works in national economy. Geometric modeling methods are considering as one of main process of research and development which have significance in formation of living environment. The problem is solved by a systematic analysis of the capabilities of geometric modeling methods and systems. Based on the analysis, the role of geometric modeling laboratory in the product lifecycle management is determined on example of Agriculture Engineering. Offering by author geometric modeling laboratory activity is considering as new – “Conceptual Design” stage of product lifecycle. The structure of the geometric modeling laboratory is proposed by working-out its framework. The system framework levels and connections are considered in viewpoint of National Innovation System, where offered laboratory joint educational, research and design organizations. The main tasks of this laboratory are highlighted based on system “Education – Science - Career”. The proposed project is a necessary engineering infrastructure in conditions of digital economy that allows to activate the implementation of innovative projects in the cooperation of education, science and production.

1. Introduction

Today, Uzbekistan is one of the most dynamically developing countries, with an annual growth rate of the economy observed since 2000. Previously, the Government planned to double gross domestic product by 2030, holding the average annual growth of the economy at 4.5%. However, the continuation of this policy required fundamental reforms, for which the country's leader identified priority areas of development [1,2]. Thanks to the measures implemented, the economy grew at a steady rate of 5.5% in 2017 [3]. The country is on the path of technical and technological modernization of all industries, which requires to be based on new, Digital Technologies. World experience has shown that continuous practical implementation of innovations that ensure quality growth in all areas, has become a driving force of social and economical development, in this regard, 2018 was declared the "Year of support for active entrepreneurship, innovative ideas and technologies" and formation the Ministry of Innovative Development [3]. It is also known that the modern economy is based on the digital technologies, the logical continuation of which was the name of 2020 the "Year of science, education and digital economy" [4]. The analysis of statistics on this issue showed the following: the growth of industry in relation to 1995 was 3.4 times, and the growth
rate of engineering and metalworking products, which are the core of this industry, was the highest, amounting to 113.9%, while the share of manufactured products in this industry was 17.5%, and it increased 10.5 times in relation to 2000. If we consider that 24% of gross domestic product is made up of industrial products and one of the main factors of its development is the qualitative and quantitative growth of Research & Development, it becomes clear how important it is to conduct them at the current level. However, the analysis shows that among the organizations that have performed Research & Development, the lowest indicator is the Design Organizations, which are the engineering infrastructure conducting Research & Development [5]. These facts point to the need to introduce synthetic design methods in this area: geometric and computer modeling, as innovative. They should lead to a qualitative and quantitative growth of Research & Development, increase the Digital Economy indicators and variety of New Products, also confirmed by the author's research [6-9].

2. Materials and Methods
To solve the above tasks, the Government is implementing reforms to form and develop the National Innovation System, which was formed in developed countries at the time [7]. The structure of the National Innovation System is presented as research, the ultimate goal of which is innovation. This system is part of a large system consisting of sectors such as "Government", "University" and "Manufacturing", as well as their surrounding infrastructure [6]. Increasing innovation activity is a very important task and it will be feasible when the sectors cooperate on the New Production. Their effectiveness also depends on the infrastructure that uses new technologies [8]. At the same time, it is necessary to note the diversifying role of Geometric Modeling in the activation of innovation, using which the "University" sector can solve many problems of the Digital Economy to organize “New Product” through Research & Development. Among the set of New Product Data, let's select its Geometric Data - shapes, dimensions, and positions that are included in the Engineering Data Group. Managing the Geometric Data based on synthetic methods, using Digital Technologies, will allow to easily and quickly adapt the New Production in Digital Economy, as an innovation. Here, "University" is considered as a sector of organizations (Universities, Research Institutes, and Design Organizations) leading Research & Development. This infrastructure provides for the exchange of Engineering Data, including Geometric Data, between organizations involved in the Product Lifecycle Management (PLM) [10,11].

3. Results and Discussions

3.1. Integrative role of Geometric Modeling Laboratory in PLM. It boils down to the fact that the use of the method, depending on the approach to the study of New Product, analytical - in identifying relationships, and synthetic - in establishing them. Until the beginning of the century, analytical methods were mainly used to solve technical problems. But the significant development of CAD technologies has expanded the possibilities of Geometric Tools, as well as the scope and front of application of synthetic methods, i.e. Geometric Modeling. Any technical objects have Geometric Parameters, which can be varied to optimize their technical and technological parameters. And the process of variation by means of Geometric Tools is a Geometric Modeling, which has a number of advantages, such as visibility, simplicity and versatility. In many tasks, they can be used much more effectively than analytical ones. Therefore, they have become widely used in the Digital Economy of developed countries, especially with the development of CAD technologies. Since CAD technologies are based on geometric principles [12,13], their development has significantly expanded the capabilities of Geometric Modeling objects in the CAD application process. Various aspects of Geometric Modeling are covered in great detail in [14]. The problem of practical application of these models is solved by the introduction of computer technologies, as well as the assessment of the information essence of these models. Geometric Modeling Systems are based on the understanding of any geometric structure as a universal information converter or, in other words, a geometric machine. In this context, a full-fledged possibility of using a computer not only as a "numerical" machine, but
also as a "geometric" machine, regardless of the real nature of the physical processes occurring in it. This concept, which allows us to abandon the numerical interpretation of problems, has become very useful for specialists in various fields, such as Design [15]. All this once again confirms the role of Geometric Modeling in the Digital Economy, which is based on an interactive design process as human-computer. In this process, the person performs non-standard operations of a creative nature (Geometric Modeling), while assigning standard operations of a routine nature to the computer, which confirms the innovative nature of the Geometric Modeling. The modern economy in these matters is based on such innovations as CALS-technologies (Continuous Acquisition and Lifecycle Support or information support of PLM processes), in which, due to continuous information support, uniform methods of process management and interaction of all participants in this cycle are provided [10,11]. Let's consider this problem by stages of the PLM, in which the proposed by author stage "Conceptual design" has an innovative value in creating the New Products in conditions of Digital Economy (Figure 1).

![Figure 1. Integrative role of Geometric Modeling Laboratory in PLM](image)

In Digital Economy, the designing process of New Production is performed using a wide range of CAD. This will reduce the design period by automating many stages of the design process, and reduce the cost of design works by conducting virtual experiments that replace full-scale ones. This facilitates and improves working conditions, improves the quality and accuracy of design [15]. Standard integrated computer system is CAD/CAE/CAM, where 1) CAD is Designing the New Products by assisting computer, i.e. the Geometric Modeling System, for example, AutoCAD; 2) CAE - Engineering analysis the New Products by assisting computer, for example, ANSYS; 3) CAM - Production the New Products by assisting computer, for example, DellCAM. In addition to standard
integrated computer system, such as ProEngineer (CAD/CAE/CAM), we can specify lower-level integration system, such as SolidWorks (CAD/CAE) or CATIA (CAD/CAM). There is without integration system, for example, AutoCAD is only a CAD system, or with high-level integration, like integrated computer system and PLM, for example, ProEngineer/Windchill (CAD/CAE/CAM/-PDM), where PDM (Product Data Management) is one of the subsystems of PLM. Note that PDM as a management system of product data, in contrast to other subsystems, uses Geometric Data of Products [11]. It shows, that the Geometric Modeling System is a mandatory and basic element of integrated computer systems, where the 3D core of the CAD system, being the mathematical apparatus for exporting Geometric Data of New Products, provides its integration with other integrated computer systems [10-12]. Projects of New Products developed in the CAD system are also applicable in other parts of integrated computer systems: engineering calculation (CAE) and production (CAM), and their Geometric Data are applicable in general for PLM, the introduction of which is an innovation in the conditions of Digital Economy. Using Geometric Database, which is part of the product’s engineering data group, requires specialists to have the necessary knowledge, skills and knowledge about Geometric Modeling. Separately created or included in the structure of engineering data, the Geometric Database provides all stages of the PLM with the necessary geometric data, which has different forms and levels: verbal, graphical, parametric, algorithmic, 2 or 3 dimensional and procedural (manual) information.

3.2. Geometric Modeling Laboratory Framework. As noted above today Geometric Modeling Laboratory has possibility can be one of main stage of PLM. This Laboratory as Engineering Infrastructure can collaborate with any engineering fields: Construction Engineering, Mechanical Engineering, Agriculture Engineering, Transport Engineering etc. So, it is important to considering its framework, which we can see on example in Agriculture Engineering, as system called “Infrastructure B” (see the Figure 2). Shall conduct structural and functional analysis of the system and its components. To bottom in problem at first shall we conduct composition of the structure not only jurisdictional subsystem B, but also corresponding to state system C and National Innovation System A as a whole. In considered National System on Agriculture Engineering participate all concerned interested parties (organizations), as its components, which the general problem is an efficient designing, production and usage of the agriculture machines. The corresponding ministry, those coordinate project realization on Agriculture Engineering present the sector “Government” as over system. The jurisdictional institutions, those providing this system by personals and projects present the sector "University". Enterprises, those releasing, exploiting and repairing agriculture machinery present the sector "Manufacturing". For determination of the problem of the proposed subsystem shall we conduct the decomposition of the systems and functional analysis their components. It does not require proof, that the system "University" is projects’ generator of the system A and proposed infrastructure B serve as subsystem of the system "University". In the course of studies the problem’s condition and by research’s result that conducted the author was revealed that, nearly all components of the considered systems B and C bluntly need for introduction in their activity, particularly at realization project "Innovative (new) production", modern designing technologies based on Geometric Modeling. On this for efficient functioning the proposed infrastructure reasonable to create the "Geometric Modeling Laboratory". This component can provide necessary Geometric Data (information, parameters, algorithms, models and methods) more than designing process, but also production processes, exploitation as well as repair agriculture machines. Main function of this component Geometric Data Management i.e. we can manage by means of these data for adaptation process of new or improvement existing product, when is organized "Innovative production". This component necessary when making and apply the integrated systems (CAD/CAE/CAM and PDM-Product Data Management) of industry, particularly new product that is innovative process in industry. At the same time managing of product’s geometric data is produced by CAD systems i.e. Geometric Modeling Systems [16-20]. In considering system:
1) System framework: Over system \(A\) – Engineering Infrastructure (as Government); Systems \(B\) - Geometric Modeling Laboratory (as University) and \(C\) - Agriculture Engineering (as Manufacturing), where \(C1\) - “Producer” and \(C2\) - “Customer” are subsystems;

2) System components: \(B1\) - “Jurisdictional HEI (Higher Educational Institutions)” , \(B2\) - “Jurisdictional Research Institutes”, \(B3\) - “Jurisdictional Design Offices (Studios)”, \(C1\) - “Agricultural machinery industry plants”, \(C21\) - “Repair and engineering workshops”, \(C22\) - “Tractor parks”, \(C23\) - “Farm enterprises”;

3) System levels: 1-National; 2-Regional; 3-Sub regional; 4-District; and 5-Sub district;

4) System connections between components along Geometric Modeling Laboratory (\(B\)): a – system’s inside connections along designing the projects, \(b\) - consecutive outside (output) connections for implementation the projects, \(c\) - reverse outside (input) connections for correction the projects;

5) \(a’\)- functional output and input connections of Geometric Modeling Laboratory (\(B\));

**Figure 2.** Geometric Modeling Laboratory framework on example Agriculture Engineering.

### 3.3. Determining the Geometric Modeling Laboratory Task.

For better understanding the importance of the Geometric Modeling Laboratory, it is necessary to highlight its tasks. The tasks are three category connected with Organizations in the modern system of ”Education-Science-Career”. We will consider this system as an innovative system, in which ”Education - Universities”, ”Science - Research Institutes” and ”Career - Design Studios”. As an example, we can consider these task again on example Agriculture Engineering. Let’s highlight the following tasks: ”Preparing Engineers Specialists”; “Conducting Researches” and ”Developing Projects” (Figure 3).
4. Conclusions

The offered project of Geometric Modeling Laboratory makes it possible to conduct cooperation between education, science and production more effectively. This is due to the fact that almost all innovative projects are implemented on the basis of this cooperation, where all the participants of the cooperation work with the geometric data of the project. That is why this project was submitted for considering to the “Investment and Innovation Department of the Governance of Bukhara Region of Uzbekistan. According to this project, was defended a dissertation, were obtained two patents, a monograph, were published educational and methodological manuals, as well as more than 60 articles and theses in National and foreign publications.

Acknowledgements

The paper materials are results of author’s researches by sponsorships of Government of the Republic of Uzbekistan. Author is grateful to the leadership of Tashkent Institute of Irrigation and Agriculture Mechanization Engineers (TIIAME), Peter the Great St. Petersburg Polytechnic University (SPbPU), Bukhara Engineering-Technological Institute (BETI), St. Petersburg State University of Telecommunications (SPbSUT) and the Bukhara branch of TIIAME for arrangement of conditions for conducting these researches, as well as to prof. D.F.Kuchkarova (TIIAME), prof. D.V.Voloshinov (SPbSTU and SPbPU) and prof. N.M.Murodov (Bukhara branch of TIIAME) their consultations as a scientific supervisor.

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