Pioneers of Russian Computers and Computer Graphics

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***Abstract*—The work of the creators of the first electronic computer of the BESM series is briefly described. This computer served as the technical basis for the first Russian project in computer graphics area. The article also tells about the activities of Russian pioneers of computer graphics, who worked for the Academy of Sciences of the USSR at the Institute of Precise Mechanics and Computer Engineering and at the Institute of Applied Mathematics.**

Keywords—computer, BESM, computer graphics, computer graphics pioneers

I. Introduction

We owe a lot to people who made it possible for us to talk about domestic computer technology and domestic developments in the field of machine graphics. Certainly, there are many such people, and it is impossible to talk about each of them in one short article. It is impossible even to list all names that are worthy of mention in such a context. We can only hope that those who are interested in the history of Russian science, domestic computer technology, domestic developments in the field of machine graphics will turn to the sheets of scientific journals and other publications and will be able to find many interesting facts and scientific ideas there, many of which have not yet been fully implemented.

To understand where the machine graphics came from, why it was what it was, and did not immediately become what it is now, one need to remember how computing appeared in the country, what was the very "computation machine" at that time. And it all started in the middle of the last century.

II. Computer That Appeared To Be Universal

In 1950, in Moscow, on Bolshaya Kaluzhskaya Street, which is now called Leninsky Avenue, the construction of the building of the new Institute of Precise Mechanics and Computer Engineering of the USSR Academy of Sciences (IPMCE) began. This building stands in this place now. Construction began not spontaneously. By this time, IPMCE already existed. The institute began with a government decree, which not only obliged the Academy of Sciences to have such an institute in its composition, but demanded that other departments provide IPMCE with all the necessary resources.

The work of IPMCE gradually unfolded, the formation of the institute's staff and the discussion of priority tasks began, but at the very beginning of 1950 dramatic changes took place in the fate of this team. Academician Mikhail Lavrentiev was appointed director of the institute, which happened very unexpectedly for everyone, and even for Mikhail Lavrentiev himself (*fig. 1*). He was a very famous and authoritative scientist, a mathematician who did a lot for science and his country. The story of his life and work can take more than one hour. For IPMCE he did a lot, although he worked in it for only two years, while leaving the kindest memory of himself. On the building of IPMCE there is a memorial plaque with a reminder that this wonderful person worked in it. His most important business for domestic computing was that immediately after assuming the position of director of the institute, he established No. 1 laboratory in its structure and invited Sergey Lebedev (*fig. 2*) to the position of its head. At that time Lebedev worked as the director of the academic institute of electrical engineering and led, in addition to its main activity in developing voltage balancing systems in power transmission lines over long distances, worked on creating a Model of an Electronic Calculating Machine – MESM.

Sergey Lebedev rightfully bears the title of father of domestic computer technology. This does not mean that there were no more scientists besides him who also worked on the first computers in the country. It would be enough to name Yuri Bazilevsky, Isaac Brook, Nikolay Brusentsov, Mikhail Kartsev, Bashir Rameev, and this is far from a complete list of outstanding scientists, creators of the first electronic computing machines. However, against the background of these brightest names, the name of Sergey Lebedev stands out.

In 1975, the Institute of Precise Mechanics and Computer Engineering of the USSR Academy of Sciences got the new name: Lebedev Institute. A little less than 25 years he worked at the institute, taking the most active part in all developments. All this time, IPMCE was the European leader in the development of the fastest computers, leaving behind both the English company ICL and French computers manufactured under the Bull brand, having real competitors only in the USA. Under his leadership, more than two dozen computer models were developed, the most famous of which were the BESM (Big Electronic Calculating Machine) series computing machines.

Of course, the main concern of Sergey Lebedev at first was associated with the formation of the team. He immediately realized that it was necessary to look for computer enthusiasts among young students. While giving lectures at the Moscow Power Engineering Institute, he told students about the BESM digital computer he conceived, talked about new methods for accelerating computing, about a new technique with which students will soon have to work as engineers (*fig. 3*).

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Fig. 1. Mikhail Lavrentiev

Fig. 2. Sergey Lebedev

Fig. 3. Sergey Lebedev is giving a lecture at the Moscow Power Engineering Institute

Nine students enrolled in Sergey Lebedev. It is curious to follow how students who have not yet suspected the existence of new computer technology, having the opportunity to learn from a person who wanted to teach them everything that he knows himself, soon became very qualified engineers. The results shown by the students of this group brilliantly confirm Sergey Lebedev's ability to discern their abilities and talents in very young people. All students subsequently became candidates of sciences, five of nine defended doctoral dissertations, they received one Lenin Prize and seven State Prizes, two of them became full members of the Academy of Sciences – Vsevolod Burtsev and Vladimir Melnikov. Their diploma projects were related to the development of different devices of the BESM computer, they were completed and defended quite successfully [1-4].

It was in 21-st of April 1951 when State Commission started its activities, and in summer 1952 building a computer was finished. It was put in the production mode by autumn of 1952. BESM computer was located on the ground floor of IPMCE building on Leninsky Avenue. During a long period of time it was solving both scientific and applied problems. In particular, this computer was used to calculate the trajectory of the rocket that delivered the pennant of the Soviet Union to the Moon.

The creation of BESM of the USSR Academy of Sciences became the most important stage in the development of domestic computer technology [5-6]. This fast-acting computer was then the most productive machine in Europe and one of the best in the world. In October 1955, Sergey Lebedev made his famous report at the International Conference on Electronic Digital Computers in Darmstadt (Germany), which made a sensation: BESM turned out to be the fastest computer in Europe. In the future, it occured that all the computers of the BESM series (from the very first BESM of Academy of Sciences to BESM-6) at the time of their creation were the best in Europe in the class of universal computers. In the structure of BESM, the main solutions characteristic of modern computers were already implemented, the useful operation time was approximately about 72%. The method of standard routines was widely used in BESM to simplify programming, which later laid the foundation for modular programming and application software packages.

III. First Graphics Project

In 1956, a grand All-Union conference was held, within the framework of which a section on computer technology worked, bringing together the best local developers [7]. Several employees of IPMCE did their presentations. The wide fame of the remarkable possibilities of new technology, which suddenly arose in the USSR, led to the emergence of new contacts within the country. One of these contacts led to the emergence of a new direction in our science – a direction that is now called “computer graphics”.

In the same year, a group of IPMCE employees consisting of Nella Tolmacheva, Viktor Alexandrov, Sergey and Nina Karabutovs, Alexander Tomilin, and their colleagues, as well as their team leader Constantine Reidik (*fig. 4*) were invited to one respectable military organization located on Frunzenskaya embankle in Moscow, building No.44. There, in a huge hall, they were shown a translucent panel with a color map of the Soviet Union, on which one could notice the marks of aircrafts flying over and near the country at that time. Everyone was asked to pay special attention to the barely noticeable lines on the map, and then led to the backside of the map, where multi-storey scaffolding was found on which soldiers in headphones moved, and putting magnetic marks on the map according to reports from remote airspace tracking stations. The shadows from the boots socks of these soldiers, pressed to the back of the map, turned out to be the weakest dashes.

The team was tasked with automating the map with the air situation. The developers were located on the first floor of the IPMCE building in room 206, directly above the room in which the BESM computer was installed. By that time, BESM, located on the ground floor, occupying its entire northern half, was the only computing resource of IPMCE. Cables were stretched from below, which, after switching several choppers on the ground floor, made it possible to switch work from BESM to a backup console assembled in room 206, in which very soon after meeting with new customers, work began on the implementation of the bitmap display with video memory.

In fact, nobody knew the terms “bitmap (raster) display” or “video memory” at that time. Reidik’s team was building “dynamic screen” (they used just this term) with video buffer on magnetic drum. The photograph shows the drum, which is now in the museum of IPMCE history (*fig. 5*). At the bottom front, there is a strip with magnetic heads installed on it, each of which is intended for recording and reading information along a separate track of the drum. In addition to the line of magnetic heads available in the drum, which allowed the computer to write information on the drum and read it from there, a second line of reading heads was made for the drum (it was called “rolling pin”). Binary information was recorded on the drum. Each bit corresponded to some single point of the “dynamic screen”. One state of the bit meant a light dot, the second state meant that this dot on the screen should be dark.

Fig. 4. Constantine C. Reidik and Alexander N. Tomilin (pictures of the second half of 1950s)

Selecting the screen itself was also a problem. The electron ray tubes of conventional TV sets were then rather small. Actually, there were few TV set models then: model named “Moscow”, and a well-known KVN-49 (named after its designers – Kenigson, Varshavsky, Nickolaevsky). Diagonally, these tubes were about 10 centimeters in size (*fig. 6*). It was necessary to watch TV by installing a water lenticle in front of it (a simple container open from above with a flat rear wall and a convex front), in which the water had to be often changed so that it would not become contaminated. Some TV viewers painted water in the lenticle with blue school ink, which made the TV screen “blue”. It was the absence of large TV tubes that led to the fact that the dynamic screen was designed using a projecting television tube. It had an even smaller tube than the tubes of ordinary TVs (about 4 cm diagonally), but very powerful. It was impossible to look at its rays with open eyes, so the rays needed to be projected onto remote screen, where a fairly clear image measuring up to 2 by 2 meters could be obtained. Such an image could well serve to display a map of the country.

To the best of its strength and technical abilities, the customer also provided assistance to a small team of IPMCE designers, especially with their personnel. At the very beginning of the work, a colonel came from the military department and brought two subordinates, a lieutenant colonel and a major. The colonel listened to the team members' messages about their work and conditions,

Fig. 5. Magnetic drum of BESM Computer

writing something in the notebook. At the end of all reports, he, looking into this book and addressing his subordinates, entrusted the lieutenant colonel with a binary numeral system, and the major with an instruction set. The order followed: "*So that by Saturday everything should necessarily be ready!*" And indeed, as the developers told later, everything was ready by Saturday, but a year later.

Project audit took place on the customer's territory. Lebedev, several generals with large stars on shoulder straps, sat in the presidium. During the demonstration, the military showed prepared pictures of moving lines of text and flying aircraft.

The most important general, who explicitly stated that he liked everything, made the summary. He was ready to give the institute any money to create a practical installation. In response, Lebedev said that the institute has extremely important government tasks that require the use of all its available resources. Lebedev was ready to transfer the documentation to any design bureau that will have to continue the project until it would be implemented. The answer was the general's loud disappointment: "Who will implement other people's ideas?" On this, the history of raster displays and video memory, as well as "machine graphics" in IPMCE was interrupted for many years.

Fig. 6. KVN-49 TV set

Indeed, at this time, IPMCE participated in several important projects. The Institute was developing a new universal computer M-20, two times more productive than the first BESM computer, the Diana computer for the fighter aircraft guidance system, and the multi-computer system for the missile defense system named "System A".

IV. Computer Graphics? It's Very Simple!

The next stage in the development of computer graphics in the country is already connected with another, no less famous computer developed in IPMCE, and named BESM-6. Lebedev loved this computer very much, he carefully prepared its development, he himself participated in it. One can talk about this computer for a long time; this is the topic of individual conferences. By the way, one of such conferences took place in 2018, it was dedicated to the 50th anniversary of the BESM-6 development. For this work Sergei Lebedev and several of his colleagues were got the USSR State Award. In 1996, Lebedev was awarded the Babbage "Computer Pioneer" medal of the computer society of the American Institute of Electronic and Electrical Engineers (*fig. 7*). The BESM-6 computer itself is now only in museums, though not so long ago it continued its production activities. However, now it is being installed at the Polytechnic Museum in Moscow. BESM-6 enthusiasts, among whom there are its developers, are trying to make this installation effective, because the reliability of this computer exceeded all expectations. For example, a museum exemplar, while it was on the production site, that is, for 26 years from 1982 year to 2008 year was active during 76053 hours. There are BESM-6 exemplars in some other museums. It may be seen in the London Science Museum near the legendary American computer CDC-6600.

It was with BESM-6 that Vadim Kobelev began his activities, to what we owe a lot for his breakthrough in the area of computer graphics in the country (*fig. 8*). Vadim Kobelev was one of the most prominent employees of IPMCE. In his youth, he arrived in Moscow on a bicycle from evacuation after World War II, during which he was in Central Asia. He became a student of the first year in physics on the new Physical-Technical Faculty of Moscow State University, later transformed to one of the best domestic technical colleges – Moscow Physical-Technical Institute (MIPT).

Fig. 7. Babbage Award Medal of Sergey Lebedev

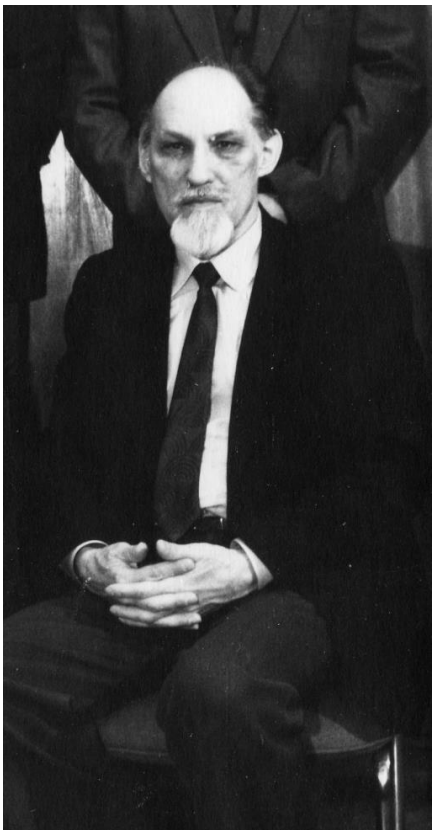

Fig. 8. Vadim V. Kobelev

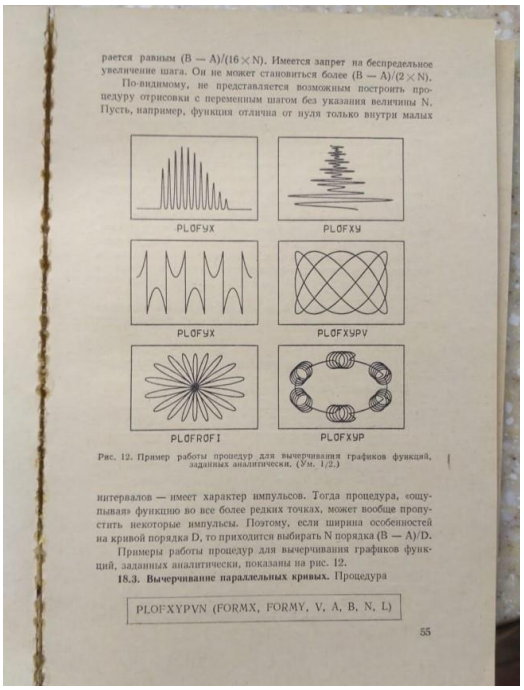

Fig. 9. Vadim Kobelev's publication on GRAPHAL system

Having been educated at MIPT and engaged in the development of memory systems on magnetic cores, Vadim Kobelev became interested in computer programming and created the original library of graphic programs in Algol-60, which was named GRAPHAL (*fig. 9*). Its main purpose was to create photo templates for multilayer printed circuit boards designed in IPMCE [8].

Vadim Kobelev was also fond of amateur graphic programming. He wrote on Algol-60 a unique set of routines that allowed the display lamps of the BESM-6 operator's console (buffer registers for loading and storing data, instruction buffers, and index registers) to draw running inscriptions and entertained employees (and sometimes, on New Year's holidays, their children and grandchildren) with magnificent electronic greeting cards.

One of the first inscriptions that Vadim Kobelev wrote on the computer console was: "*Go to the drugstore and buy something for tea-party*". He learned to draw pictures on the alphanumeric printer, displaying complicated scenes with shadows and semi-shades on an alphanumeric device (*fig. 10*).

On the spring Women's Day, he presented his IPMCE female colleagues programmed and displayed gifts that aroused general admiration (*fig. 11*). He created the first computer games on BESM-6 with graphics on Hungarian alphanumeric displays VT-340 and VDT-32100: the game in "NIM", "Horse Racing" (for the smallest children), "Criminal Investigation", "Cave" and many others.

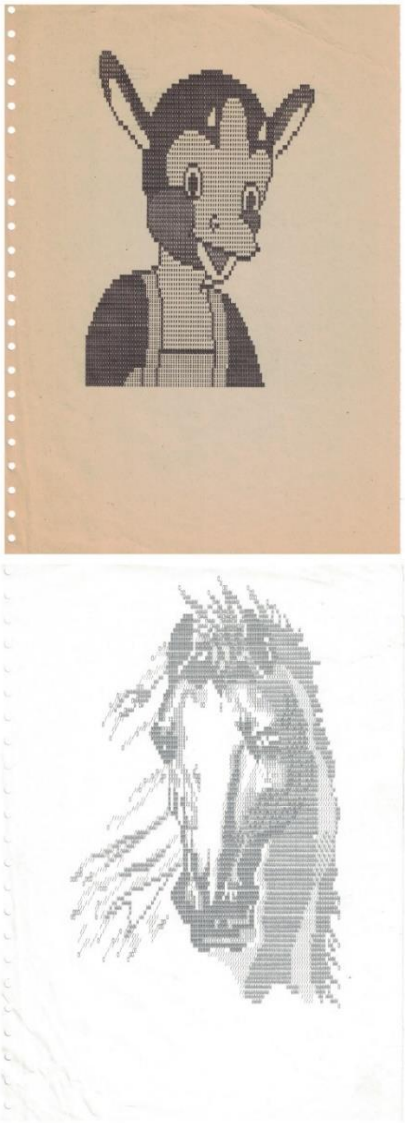

Fig. 10. Computer graphics performed by Vadim V. Kobelev

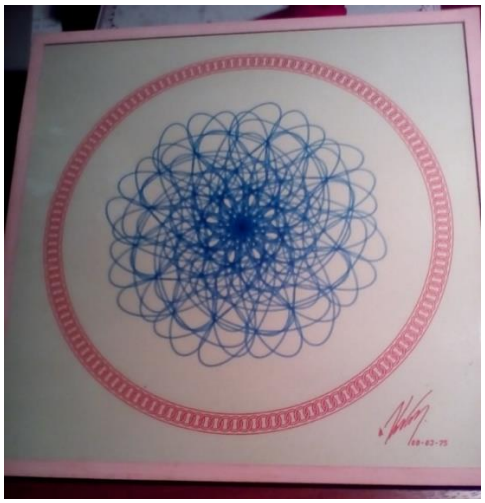

Fig. 11. Computer graphics performed by Vadim V. Kobelev (8th of March, 1975, International Women's Day)

V. Computer Graphics As Mathematics

At the same time, work on computer graphics was unfolding at the Institute of Applied Mathematics (IPM) of the USSR Academy of Sciences, which later received the name of Mstislav V. Keldysh, who for a long time was the director of this institute. The achievements of this scientific institution in the computer graphics area are inextricably linked with the name of Yuri M. Bayakovski (*fig. 12*). His work in this area began back in 1964, when, together with Tamara A. Sushkevitch (for her work [9]), he made a short film that demonstrated the possibilities of visualizing the flow of a volumetric geometric body, in particular, a cylinder, with plasma.

Computer programmers created a sequence of frames that was output to the electron beam tube. At this time, there were already so-called "sign-printing" tubes that made it possible to demonstrate text information coming from computers. There were also those that also contained a second electronic spotlight with its own deflecting system, capable of superimposing an additional graphic image on the character information. In the work of Yu. Bayakovski and T. Sushkevitch, the famous computer "Spring" was used. It was no longer a lamp, like the first BESM, but a solid-state computer developed at the Design Bureau of Industrial Automation, from which the Quant Research Institute subsequently grew.

Fig. 12. Yuri M. Bayakovski with his colleagues in the Institute of Applied Mathematics, the USSR Academy of Sciences

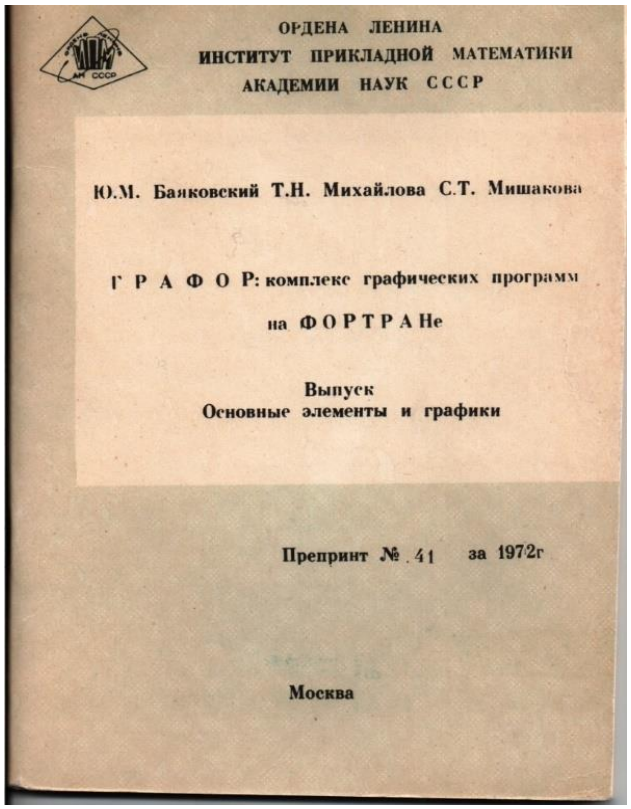

Fig. 13. The first publication on GRAFOR system made by Yuri M. Bayakovski and his colleagues

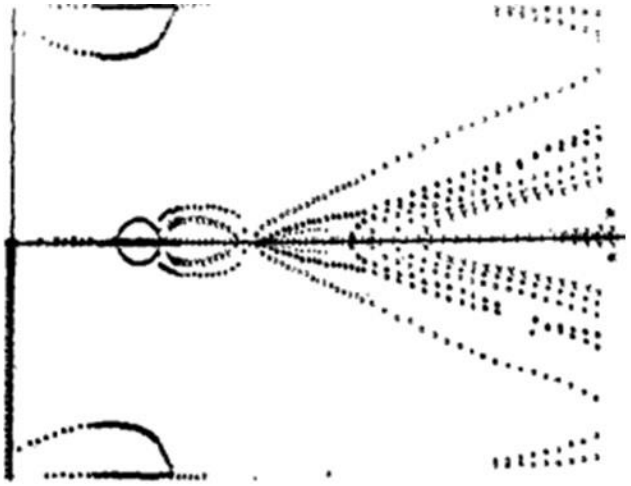

Fig. 14. The first picture drawn in GRAFOR system by Yuri M. Bayakovski

But the main contribution of Yuri Bayakovski to the formation of a new scientific direction was in the development of the graphic program library GRAFOR, begun at the IPM in the late 1960s (*fig. 13-14*). The name of the library clearly leads to thoughts about the Fortran programming language, from which compilers at that time were already available on almost all computers produced in the country. There was also more advanced peripheral equipment at this time. Local devices were produced in the country, and foreign graphic printers and graphic displays were purchased. As one of the main tasks, the task of automating the production of photo templates for printed circuit boards was then considered. The development of the technique of printing current-conducting layers on plastic boards went very quickly then. For example, IPMCE was

able to produce PCBs with 28 layers. It made it possible to almost completely get rid of the mounted installation of elements and significantly reduced the cost of manufacturing computer equipment at serial plants. GRAFOR helped to solve this difficult task [10-11].

The GRAFOR library included more than 400 different programs, access to which was possible from user programs written in a variety of languages – Fortran, Algol-60 (a variant of the Algol-GDR system), PL/1, autocodes and assembler languages.

Since the library itself was written in Fortran, it had a high level of portability. Though initially the library was created for the BESM-4 computer (solid-state version of the Lebedev's M-20 computer), it was later ported to the M-222 (also a version of M-20), to BESM-6, and to several models of ES computers (IBM/360 analog), to SM-2 and SM-4 (clones of PDP computers), and to some foreign computers – CDC-6500, Cyber-172, Eclipse, Nord, PDP-11, IRIS-80. Various graph plotters (ES-7051, ES-7052, ES-7053, ES-7054, AP-7251, AP-7252, ITEKAN, ATLAS, CALCOMP, BENSON) and displays (ES-7064, SIGDA, EPG SM, VU-2000, TEKTRONIX) were allowed as peripheral devices. The work of Yu. Bayakovski was in great demand. Fig. 15 shows 12 frames of one of the movie fragments taken from the computer monitor screen in June 1973 using the GRAFOR system [12-14]. The film contains seven fragments (2000 frames each) from various variants of the span of a massive body (a bold point in the drawings) past the galaxy. The figures (in projection to the galactic plane) refer to the variant of a body with a mass equal to the mass of a galaxy flying near a galactic disk (with parameters close the values of our Milky Way galaxy), perpendicular to its plane, with twice the parabolic speed. Time is given in billions of years. The initial moment corresponds to the greatest rapprochement. In total, the modeling period covers four and a half billion years.

The main characteristics of the GRAFOR library (*fig. 16*), which over time was developed and documented very fully and carefully, allowed academician Andrey P. Ershov to call it not just a library, but a real programming system, that is, a full-fledged software product in the modern sense of this term.

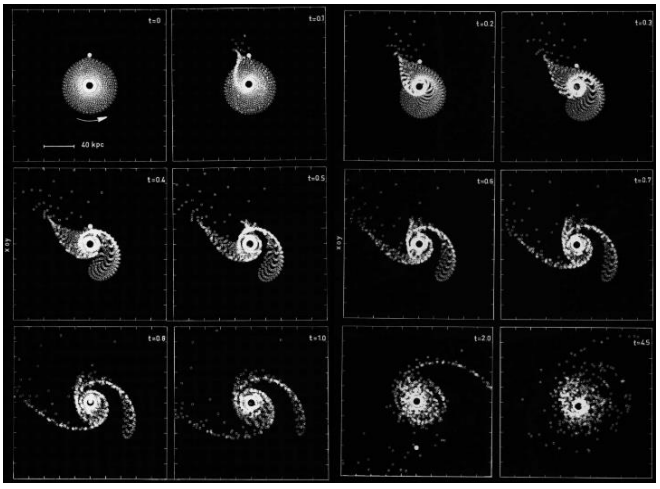

Fig. 15. Frames from the film on graphical modeling of processes of intergalactic interaction

Fig. 16. Basic features of GRAFOR system

After a while (in 1985), the developers published a book on GRAFOR in mass circulation, and it became a guide for all programmers who created graphic applications, not only using the Fortran language. This book was highly appreciated by academician Andrey P. Ershov. Yuri Bayakovski was very proud of the feedback received from him (*fig. 17*). Users got at their disposal a powerful software tool that made it possible to work with both two-dimensional (flat) objects and three-dimensional (spatial) objects described by functions from two variables. At the same time, various types of representations of objects were allowed – using surface projections and using isoline maps.

Besides GRAFOR Bayakovski had another merit: having prepared in 1970 (together with Vsevolod Shtarkman), a report to the second All-Union Conference on Computer Programming, Bayakovski used the term "*computer graphics*" for the first time in a publication in Russian, and it is still in use now [15]. Bayakovski's PhD dissertation was also devoted to computer graphics. It was titled "Analysis of methods for developing graphic computer software". For more than 30 years, Yuri Bayakovski taught the course "Machine Graphics" at Moscow State University, constantly updating it.

In 1990, Yuri Bayakovski was officially recognized as a pioneer of computer graphics. He was awarded the corresponding certificate, which noted that he made an undeniable contribution to the birth of a new industry, making a breakthrough in the future (*fig. 18*).

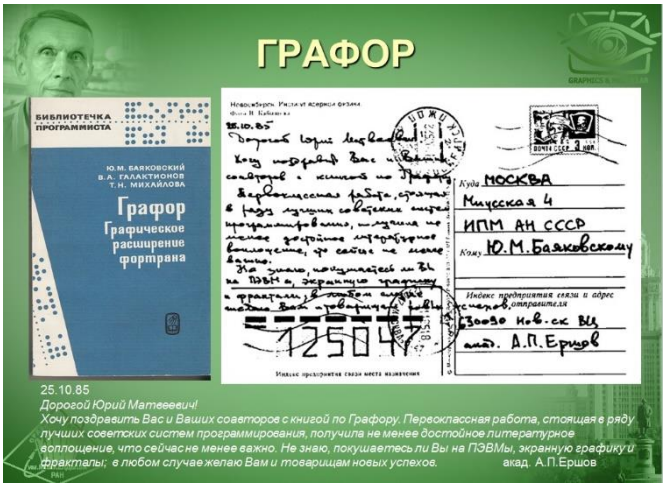

Fig. 17. Academician Andrey P. Ershov's letter written for Yuri M. Bayakovski

Fig. 18. Yuri M. Bayakovski – Computer Graphics Pioneer

Of course, we must not forget the contribution made by Yuri Bayakovski to the organization of Graphicon international conferences. He was the driving force behind the conference. Thanks largely to him, the conference was able to overcome the difficulties of the transition period and become a grandiose all-Russian forum, annually gathering specialists from different countries.

Since 1989, Yuri Bayakovski was a member of the editorial board of the Programming and Computer Software journal (in Russia is called – "Programmirovanie"). In the first issue of the journal for 1988, the section "Software for automatic processing of graphic information" appeared, and since 1989, with the advent of Bayakovski, the stable phrase "computer graphics" appeared in the title of this section. In the formation of this heading in the journal, the permanent authors and organizers of the conference, Graphicon Yuri M. Bayakovski and Stanislav V. Klimenko, who for a long time was chairperson of the conference Programme Committee, made a huge contribution. Since 1992, the best reports of the participants in the Graphicon conference began to be published in separate issues of the Programming and Computer Software journal [16].

VI. Conclusion

With this work, the authors wanted to remind readers of people who started computing and computer graphics in our country. We owe a lot to these people. They were our teachers. They were teachers of the teachers for our younger colleagues. All of us must continue to learn from them in order to teach others and not interrupt the movement of scientific thought forward and forth.

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