50th anniversary of the Keldysh Institute for Applied Mathematics (KIAM). 40 years of Computer Graphics in KIAM.

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PRELUDE

Origination of computer graphics (CG) dates back to the early 1960-s. A noticeable event marking the birth of the new discipline was Ivan Sutherland’s thesis (1963) where he discussed prospects of the interactive graphical interface between a human and a computer. Nearly at the same time (1964), the first CG application was demonstrated in KIAM (Y.Bayakovsky, T.Sushkevitch) – visualization of plasma flow over a cylinder presented as a series of frames displayed on the charactron lamp surface. This result was recognized by ACM SIGGRAPH CG Pioneers Club where Y.Bayakovsky was affiliated as a member in 1991.

New stage of CG research in KIAM began in 1967 when the CalComp graph plotter and then a vector display became available. In 1970, the first publication in Russian was issued in KIAM where the term *computer graphics* was used (Y.Bayakovsky, V.Shtarkman). In 1971, the film production system was implemented for SDS-910 computer (Y.Vershubsky, G.Borovin, A.Platonov, e.a.). It generated series of image frames showing behavior of a robot overcoming obstacles under control of an operator.

1. THE EPOCH OF GRAFOR

At the same period, development of a package of FORTRAN graphical programs began. Initially the package supported just output of graphical primitives to a graph plotter (and later to a display); using these features it was possible to draw charts of 1D functions. Later the package was extended with more graphical features – shading, clipping, spline interpolation, affine transformations, visualization of surfaces specified by 2D functions, etc. In 1977, in recognition of the great importance of CG in educational and research areas of computing, the CG department was established in KIAM. It joined the people involved in GRAFOR development and other CG research and education activities. In 1985, the book *GRAFOR – Graphical extension of FORTRAN* was issued (Y.Bayakovsky, V.Galaktionov, T.Mikhailova) . By that time, GRAFOR evolved to the classic graphical library well known and widely used in many institutions, universities and industrial enterprises of the Soviet Union and countries of Eastern Europe. At present, it is available on MS Windows and UNIX platforms and continues to be of interest as an instrument for visualizing results of scientific calculations.

2. GRAPHICON: START OF INTERNATIONAL COLLABORATIONS

At the end of the 1980-s, because of the dramatic changes in social and economic life in the countries of the former USSR the domestic demand for research and development dropped nearly to zero, and the traditional (soviet) financing of science vanished. Fortunately, the changes had their positive side opening wider opportunities for international contacts and collaboration. In 1991, the first in Russia International conference on computer graphics – GraphiCon – was organized and held with active participation of KIAM and partial support from the ACM SIGGRAPH. A number of prominent CG specialists came to Moscow and delivered lectures and reports to their Russian colleagues. The conference had great success and became annual. It allowed many Russian specialists to establish contacts with their foreign colleagues.

In 1992, GraphiCon contacts gave start to the collaboration of the KIAM CG department with the Japanese company Integra, one of the world wide leaders in high realistic CG. Due to this collaboration, the KIAM CG research staff was saved; moreover, specialists from other institutions and postgraduate students were attracted to cooperative projects. Cooperation, in its turn, required serious revision of the style and contents of the work putting it mostly to the commercial basis.

3. CG IN KIAM: MAIN AREAS OF R&D

Initially efforts were concentrated on the problem of physically accurate simulation of light propagation in arbitrary media. The ray tracing technology based on the Monte Carlo approach was elaborated, which provided accurate calculations of lighting in real scenes and rendering of images of photorealistic quality. The technology proved to be highly efficient and later was successfully applied to simulation of complex optical systems – luminaires, light guiding systems like those used in modern LCD monitors, dashboards, etc. The systems of this kind have a complicated internal structure including surfaces with complex microrelief where light undergoes billions of interreflections. It should be noted also that practical usability of optical simulation requires very high accuracy of results.

Other research direction at that period was simulation and visualization of materials with complex optical properties like multi-layer pearlescent and metallic coatings whose appearance varies with the angle of viewing and angle of illumination. The software developed in the scope of this project supports a "bi-directional" paint simulation. A user may simulate paint appearance based on its composition data (number of layers, properties and concentration of metallic/pearlescent flakes or pigments in each layer, properties of the base layer, etc.); alternatively, a paint composition may be calculated from the specified appearance characteristics (color and spread of gloss, glitter and shade, concentration and size of sparkles, etc.).

Other examples of optically complex materials are cloths. Cloth simulation required extension of the existing light simulation approach with methods of stochastic ray tracing. Appearance of a cloth is calculated based on its physical and structural parameters, which include deterministic (e.g. shape and optical properties of fibers, number of fibers in a yarn, knitting/weaving pattern) and probabilistic ones (fiber distribution along yarns, fiber surface roughness). The cloth simulation software allows visualization of cloth appearance without its actual manufacturing.

From the very beginning of the work in the area of lighting simulation, there existed the vital necessity of accurate measurement of the light scattering properties of materials – coating samples, lamp reflectors, elements of LCD, cloths, etc. As far as traditional optical devices were of little use because of the multidimensional character of the data required, the original optical installation was developed at KIAM for measurement of spectral and spatial scattering of light by an arbitrary material sample. The uniqueness of the equipment is in its ability to measure the full optical characteristics of the material – reflection and transmission of light for all possible illumination and viewing directions.

Besides accurate lighting simulation, rendering of realistic images requires taking into account the specificity of human visual perception. To meet these requirements, the rendering software was extended with support of such factors as the non-linear character of brightness and color matching, glare around bright light sources, the effect of exposure in rendering of wavy water surfaces, and others.

The system was also enhanced by possibility to use High-Dynamic-Range Imagery (HDRI) to define the lighting for a 3D scene. This technology allows to use captured real-world illumination as a source light for the scene. As a result illusion of realistically integrated model within the scene is created.

One more area of research in KIAM tightly connected with CG is computer reconstruction of artificial reality. In particular, the algorithmic solutions and the corresponding software system for reconstruction of 3D architectural objects from photos or video were elaborated. The system has multiple practical applications. As an example, it is used for preparation of background scenes (like city or country views) with automatic detection of camera position and lighting conditions. It is then possible to create "photomontage" scenes by adding other 3D objects to a background scene (for example, a car from the library of geometric objects).

4. CONCLUSION

Computer graphics research in KIAM has come into being under unfavorable conditions of isolation from the international scientific community. Nevertheless, it managed to achieve serious results in the area of visualizing results of scientific calculations. The KIAM CG team turned to be able to survive in perturbations of the "perestroyka" and continues work under new conditions. Using advantages of international collaboration, the CG specialists could apply their research and development potential to new tasks – physically accurate lighting simulation, design and simulation of optical systems, simulation of optically complex materials, and others. The CG team is keeping trace of the latest ideas and trends in CG and continues research in the newest, challenging areas – such as real-time ray tracing, rendering applications on the Internet, image based lighting, others.

About the authors

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