The “Giloi’s school” of Computer Graphics

-It’s start in Berlin and the following impact for this technology and IT discipline in Germany and in Europe-

by

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Abstract

We describe in this article early developments of Computer Graphics in Germany, which were initiated in Berlin by W. Giloi when he started there in 1965 R&D in Computer Graphics hardware and software. Two of his former Ph.D. students and Co-Authors of this paper gave early substantial contributions to key developments in Computer Graphics like Z-Buffer and Raster Technology, Device-independent Graphics and Graphics Standards.

As a result of all these activities and developments Computer graphics is today in Germany a very well accepted and most important IT discipline.

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1 Starting Computer Graphics in Germany (W. K. Giloi)

W. Giloi, Berlin (1965)

In 1965 I became Professor of Information Processing at the Technical University of Berlin (TUB). I came from the industry, where I had been in charge of the analog and hybrid computer business of AEG-Telefunken. Being an electronics engineer with a strong background in analog and hybrid simulation, I was primarily interested in computer design, digital simulation, digital signal processing, and artificial intelligence, rather than in the classical business EDP. My goal was to make the use of the digital computer as interactive as that of the analog computer, and my vision was to accomplish that by enabling the user to communicate with the computer via graphical interfaces as well as—eventually—through the spoken word.

Following a recommendation of the German Science Foundation, my chair at the TUB was one of the newly established "information processing" chairs in Germany. In addition to a generous funding by the TUB, the Volkswagen Foundation financed us a hybrid computer system, consisting of the Telefunken RA770 analog computer and the powerful Scientific Data Systems 24-bit minicomputer SDS930. As a novelty, SDS offered a large-screen vector display with a "light gun." This provided a powerful graphical workstation—to the best of my knowledge the first of its kind at a German university.

We implemented a variety of interactive systems with innovative GUIs. To ease the transition from analog to digital simulation, we developed the continuous simulation system SIESTA [1]. SIESTA was the first system of its kind where the user could describe the simulation in mathematical form, i.e., by a set of ordinary differential equations. Yet if the user wanted to use an existing analog diagram (or preferred to think in terms of such diagrams), (s)he could pick with the light gun from a menu all kinds of analog components, place them on the screen and connect them to the desired analog computer diagram. SIESTA would then translate the diagram into the corresponding differential equation system. This interactive "pick and place" technique was a novelty and became a model for the kind of graphical interaction used to this day. Another project was the graphical anamnesis tool AMANDA [2]. AMANDA displayed an outline of the human body, on which the user could mark areas of complaints. In response, the system would ask diagnostic questions and deliver at the end an anamnesis. Last but not least, we used already computer graphics as the medium for representing results of scientific computations. Just two examples: we used graphics to display the Fourier or power density spectra computed by a special-purpose, high-speed FFT hardware built in our lab and for manipulating the formants for speech synthesis by the vocoder principle. This was all quite advanced for the late sixties.

However, for us computer graphics was more than just the means for creating GUIs for various applications: In the evolving field of computer graphics, CG research became for us an end in itself. What I was primarily interested in was the following issues:

- devising high-level language constructs for graphical programming, i.e., for creating graphical objects and enabling user interactions, typically realized as extensions to existing high level languages such as Fortran and APL [3].
- developing efficient algorithms for determining the visibility of the elements of 3D-renderings of surfaces and solids [4].

I suggested to my Ph.D. student José Luis Encarnacao to develop more efficient strategies and algorithms for solving the visibility problem. In his seminal thesis [5], José presented two innovative approaches, the *priority method* and the *scan-grid method*. The priority method works on (convex or concave) polyhedrons, while the scan-grid method applies to arbitrary curved surfaces that are rendered as grids of curved lines. While the priority method competed with already existing algorithms, the *scan-grid* method was unique. It can be viewed as a forerunner of the various shading algorithms used to this day for the rendering of 3D-surfaces.

José's work was supported by a number of graduate students. He and his students became the most potent computer graphics research group around 1970 in Germany. José worked with me on concepts of graphical programming languages and programming packages and their implementation [3][6]. It was our endeavor to put the methodologies we had developed and the know-how we had gained to practical use. To this end, I established at my department of the Heinrich-Hertz-Institute a development group for graphics-based application software with José as the leader. We received contracts from the industry for implementing elaborate software packages for graphical data acquisition and processing. José and his team did a marvelous job. The success of this work had to be equally attributed to José's scientific brilliance and his superior ability to plan and schedule a complex development project, assign its components to his team members according to their capabilities, and inspire and support them to do an outstanding job. He would exhibit this rare combination of scientific brilliance and superb managerial proficiency throughout his entire career.

W. Giloi (2001)

The scope of our research ranged from innovative computer hardware to programming languages and tools to the implementation of system and application software. Therefore, it was quite natural for us to design specific hardware for high-speed coordinate transformations and 3D- rendering. Following the technological progress, these activities shifted in the early seventies from the vector display to the raster display. This work was primarily the project of another Ph.D. student of mine, Wolfgang Strasser, who came up with a number of innovative hardware solutions, including the invention of one of the most important concepts of computer graphics: the Z-buffer [7]. It was an exciting time!

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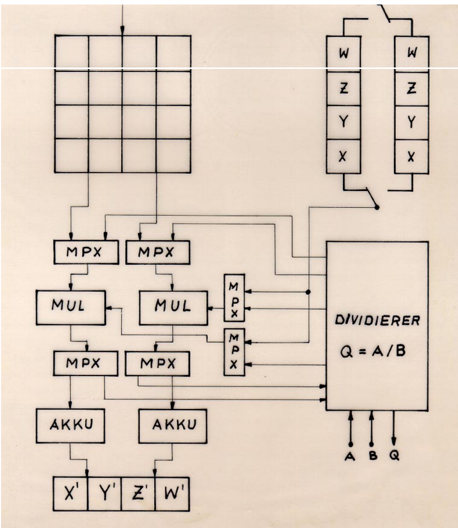
2 Early Graphics Hardware Development in Berlin(W. Straßer)

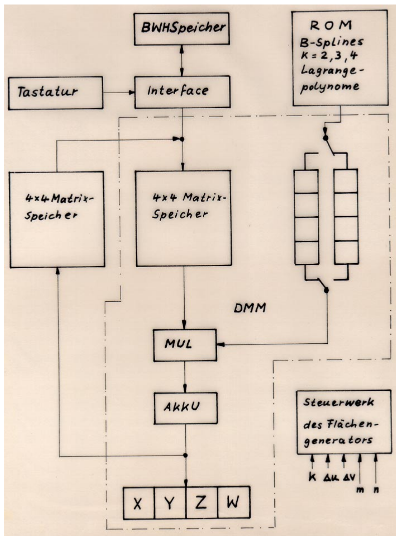
W. Straßer. Berlin (1974)

Graphics systems in those days were exotic and extremely expensive machines. Their performance required a powerful host computer, since operations like vector generation, curve and surface generation, geometric transformations, clipping, and even screen refresh were the task of the CPU. We realized that for truly interactive graphics all these functions had to be performed by dedicated hardware, and our proficiency in electronics encouraged us to start such a development. The model to follow was set by newly founded companies like Evans and Sutherland and ADAGE. Our goal was to create a modular vector graphics system as shown in the system diagram. All components shown were realized between 1971 and 1973.

The most crucial and challenging component was the digital matrix multiplier/divider DMM, because this component had to be as fast as the vector generator, which was designed to exploit the maximum bandwidth of the monitor. This goal



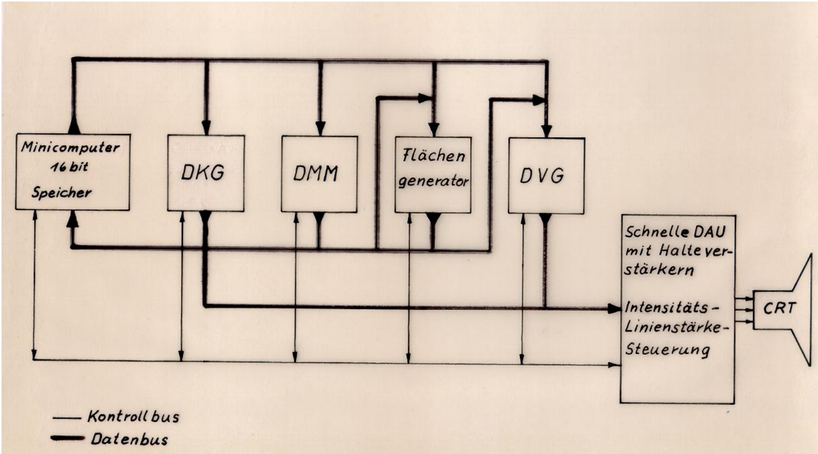
Digital matrix multiplier/divider



Curve and surface generator

was achieved by using two multipliers built of bit slice modules. The multipliers were used not only for vector-matrix-multiplication, but also for an iterative division scheme. The division employed a division table stored in a ROM; therefore, it needed only one iteration to achieve an accuracy of 16 bit. A full (4x4)-matrix transformation, including perspective division with 16 bit accuracy, was performed in 4 microseconds, which met all our requirements. In the overall design of the vector graphics system this component was relatively expensive. Therefore, it was expanded into a curve and surface generator for parametric patches, capable of calculating B-spline patches of degree 2and 3 and Lagrange polynomials of the same degrees for interpolation tasks.

Our surface generator created shaded surfaces according to Lambert´s law. The grey values in the corner points of the tensor product patches were calculated using the angle between the surface normal and the direction to the point light source. The grey values of the points inside the patches were derived from these corner values along the u-or v- parameter lines, using the appropriate B-spline



Modular graphics system architecture

polynomials. Color was not yet possible, since the vector monitors were monochrome. The shaded surfaces looked on the vector screen quite perfect as long as no occlusions occurred. Occlusions caused a multiple writing of parts of the screen, resulting in areas brighter than the calculated brightness of the surface, an effect that stemmed from intensity accumulation in the phosphor. To avoid this, we had to find a way to avoid multiple writing at the same position. As a result, **the notion of the z-buffer was born**. Of course, in those days we could not dream of having the huge amount of storage capacity required to realize a z-buffer. Therefore, this seminal idea was mentioned in my PhD thesis but not realized.

A second track of graphics hardware development was triggered by the need of the industry to have sophisticated process control stations with graphics output and control input in power plants. The cheap and reliable TV-screen seemed to be the right display device because of the inherent capability to display surfaces as well as the mandatory color. In Giloi`s group at the HHI we developed and built the first truly interactive process control displays in Europe, based on color raster display technology, equipped with sophisticated symbol-, vector- and character generators.

W. Straßer, University Tübingen, Germany (2001)

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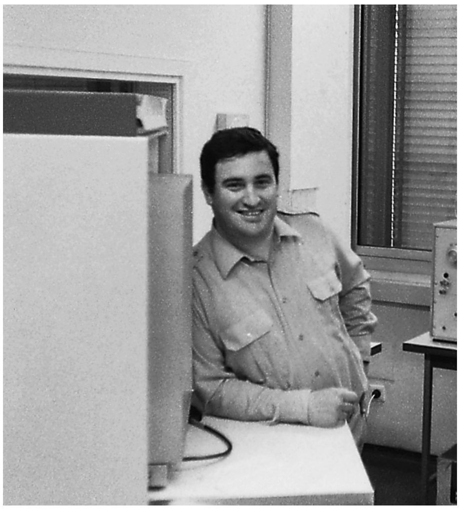
3 The german roadmap to the Graphical Kernel System (GKS) and to the other Graphics Standards (J. L. Encarnação)



J. Encarnação in Berlin (1970)

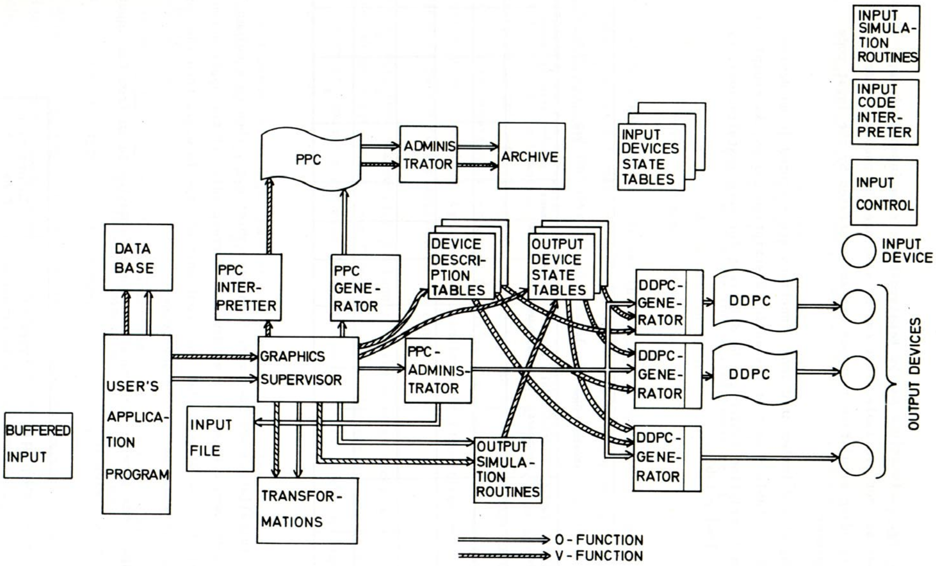
Based on the R&D work in Graphics Software developed in Berlin (see [3], [4], [5] and [6]) between 1968 and 1972 and further work done under the responsibilities of W. Giloi and myself in Saarbrücken (see [11] and [12]) it was quite clear that there was a need for a Graphics Standard. The needs for such a standard were in Europe user´s driven, therefore specially 2D-oriented and strongly considering storage tubes and plotters as the classical Graphics Devices. German experts were at that time not very well know and therefore also not very well accepted within the international Computer Graphics community. This changed dramatically with the development of GKS in Germany [12] and its successful further development to an International Standard [13]

By the late 1960´s, common techniques for use with stand-alone of satellite refresh display systems began to appear. Similarly, a certain amount of standardization was beginning to appear in the packages used for plotters. For example, GINO and GHOST began to gain acceptance in the UK in the

IDIIOM – The Graphics System used for early developments in Computer Graphics in Saarbrücken and in Darmstadt

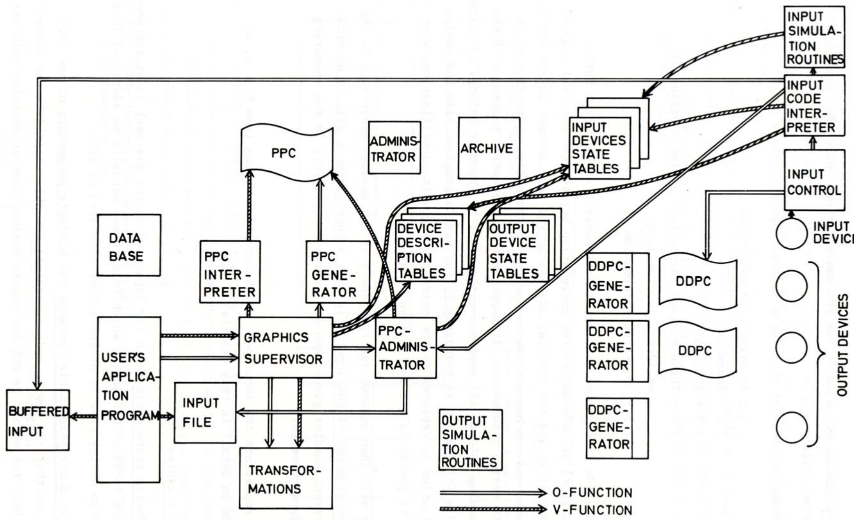
early 1970´s. In Germany GMB, GRAFSY, UGP, and PHILDIG were in use as graphics packages and Calcomp-compatible packages became prevalent in the US. The GPGS package became widely used, especially in the Netherlands and Norway.

In the midst of this changing technology graphics standards started emerging. GKS allowed easy portability of graphics systems between different installations. Large CAD suites should be able to move from one installation to another with quite different hardware without substantial modification of the overall program structure. To achieve this, the application program control had the appearance of graphics primitives on a particular device.



GKS output on a virtual device [12]

GKS divided the output of graphics into two distinct parts. The first produced output on a virtual device space called *normalized device coordinates*. The second allowed individual workstations to



GKS input control[12]

interpret this virtual space in a way specified by the application program [14].

In the US the ACM SIGGRAPH Graphics Standard Planning Committee formed 1974 developed an early concept called GSPC. After the “Sellac I” workshop in France [15] the specification of a core graphics system was developed under the leadership of A.. van Dam. GSPC was a full 3D core system.. I started in 1975 in the German Standardization Institute, DIN, a group also aiming at designing a graphics core system. The group which I chaired produced several versions of the Graphical Kernel System. One major difference between the two proposals was that GKS, a 2-D system, was significantly leaner in functionality than the GSPC core system.. GKS was there processed by ISO/TC97/SC5/WG2-Graphics. The inaugural meeting was held in Toronto in August 1977. On October 9, 1981, GKS 7.0 was accepted as an international draft proposal [16], [17] and registered in 1982.

GKS contributed in Germany very strongly to the development of Computer Graphics and its acceptance as a discipline. The GKS functionality gave a functional reference model for the all field, its technologies and applications. Later international activities like PHIGS, Open GK, GL, etc. also partially profited from that. But more than that GKS made the start of the development of a large constituency of experts in Germany with a strong international acceptance and relevance. Today Computer Graphics is one of the strongest and most reputable IT disciplines in the country [18].

J. Encarnação, TU Darmstadt, Germany (2001)

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4 Summary

In this short report we describe how we saw Computer Graphics starting and developing in Germany in the late 60´s. As a result of that today Computer Graphics is a most prestigious and one of the most important IT disciplines and enabling technologies in the country.

We call this article “The Giloi´s school of Computer Graphics” because all started with W. Giloi´s activities in Berlin at the technical University of Berlin in 1965. Two important chairs and very active groups for Computer Graphics in Germany are today under the responsibility of two Ph.D. students from those days (J. Encarnação - – now in Darmstadt – and W. Straßer –now in Tübingen). The description of two main contributions (Hardware: Z-Buffer; Raster technology; software: device – independent graphics software, GKS) with origin in the Berlin activities show as examples the early impact of this development of Computer Graphics in general, specially in Europe and even more in Germany. In order to get more information on what Computer Graphics is today in Germany we refer to Computer Graphics (ACM SIGGRAPH Quarterly), August 2001, or to http://ls7-www.cs.uni-dortmund.de/cgotn/.