

DEPARTMENT: VISUAL COMPUTING: ORIGINS

The Origins of Computer Graphics in Europe: Part 2—The Early Spreading of Computer Graphics in Europe

José L. Encarnação , Technische Universität Darmstadt (professor emer.) and Fraunhofer Institute for Computer Graphics IGD (retired director), 64289, Darmstadt, Germany

“The Origins of Computer Graphics in Europe,” is being published in two parts: Part 1, published in the March/April issue of IEEE Computer Graphics and Applications (IEEE CG&A), is subtitled “The Beginnings in Germany”; Part 2, published in this May/June 2023 issue, is subtitled “The Early Spreading of Computer Graphics in Europe.” I was a participant, contributor, and witness to the events reported here and I relate my personal story along with the broader history. Part 1 describes the origins and successful evolution of computer graphics in Germany, starting in 1965, and includes details of the people and subject matter of the earliest research groups. It describes the efforts undertaken to establish computer graphics as a proper academic discipline, including the founding of EUROGRAPHICS, and creation of institutes for both basic and applied research in computer graphics. Part 2 continues the story with a focus on activities contributing to the growth of the academic and industrial computer graphics communities across Europe and documents the two IFIP workshops held at Seillac and the development of the GKS Graphics Standard. Over the years, computer graphics gained respect and importance as a component of the computer science curricula and became an important tool and enabling technology for applications for industry and for the IT market in Europe.

PART 2

This article is Part 2 of the overview, retrospective paper “The Origins of Computer Graphics in Europe,” published in two parts and describing how computer graphics was developed and established in Germany and in Europe as an information and communication technology (ICT) tool and IT-enabling technology for the IT market. Overall, the period addressed in the article is from 1965 to 1995.

Part 1 of the overall paper, published in IEEE CG&A in the March/April issue 2023, concentrates primarily

on the establishment of the Computer Graphics Hub in Darmstadt (1975–1994) in Germany,² on the Foundation of EUROGRAPHICS in 1980, and on how computer graphics developed to a well-accepted, important discipline within computer science, especially in Germany. This article is Part 2 of the overall article and describes the early spreading of computer graphics around Europe, especially and in more detail, in the United Kingdom (U.K.) It then addresses the important milestones for this process of spreading and establishing computer graphics in Europe. These milestones were the *lighthouse* initiatives and activities of the Seillac I and Seillac II workshops (1976 and 1979) and of the development of GKS, the first graphics standard, published by ISO in 1985. Each of these is described in this Part 2 of the article, which ends with an extensive list of references and an acknowledgement.

THE ORIGINS OF CG IN OTHER EUROPEAN COUNTRIES

The article presented and described in Part 1 focuses only on the beginnings of computer graphics (CG) in Germany that arose from the activities of the Gilo School of Computer Graphics¹ and its development based on the Computer Graphics Hub in Darmstadt.² There were of course similar and equally important developments going on at the time and in parallel all over Europe. The origins of CG in every European country were obviously very much dependent, in intensity and in quality, on a number of factors. The factors included: the situation with the reality of the emerging computer science and information technology departments at the local universities; the national political and economic conditions and technology priorities; the local market needs; the national education, research, and innovation infrastructure; and the existing experts, the individual “local players and local driving forces,” which were at the time already interested in and contributing locally to teaching and to research in the new emerging technical area of computer graphics as part of computer science and information technologies. It is not possible to clearly and completely separate the origins of CG in Germany from the origins of CG in Europe. Since the developments in Germany were by themselves of great importance *during* the initial phases and since I was personally not only an essential contributor but also had a strong participation and some overall influence in the starting of CG in Europe, the description of the early beginnings in Germany in Part 1 may be also seen as an appropriate and quite representative overall description for the origins of computer graphics in Europe.

Many of the early pioneering developments in other European countries were nevertheless equally important to those in Germany and had influence also on the origins of CG in Europe. They all deserve to be presented and described in this article. However, restrictions in the size of the article do not allow me to describe and discuss here in detail their role and impact in the development and spread of computer graphics in Europe.

This is, among many possible examples, especially the case for the activities in France at Thomson CSF (R. Guedj) and at INRIA (A. Ducrot); in Italy at the Universities of Milan and Pisa (U. Cugini, G. Valle); at CNR (B. Falcidieno); in Sweden at the Royal Institute of Technology (L. Kjelldahl); in Switzerland at the Universities in Geneva and Lausanne (N. Magnenat Thalman at MIRALab and D. Thalman at EPFL) and at CERN (C. Vandoni); and in The Netherlands at CWI in

Amsterdam (P. ten Hagen). Several other European countries and individuals could be named and referred to here. For those readers interested in more information on these local activities and developments, some references for “Computer Graphics in Europe”^{5,6,7,8,9,10} are included in the list of references at the end of the article.

There is another European country that served together with Germany as an important pillar and had a major impact on the origins of computer graphics in Europe, namely the U.K. These activities and contributions of the U.K. will be briefly described in the following section.

DEVELOPMENTS IN THE UNITED KINGDOM—THE SECOND PILLAR FOR THE ORIGINS OF COMPUTER GRAPHICS IN EUROPE

F. R. A. Hopgood and D. Duce report^{11,12} that prior to 1966 research use of computers in the U.K. was dominated by the Atomic Energy Authority (AEA) with Weapons Research (AWRE) at Aldermaston and the Atomic Energy Research Establishment at Harwell. The Atlas Computer Laboratory was at Chilton and later fusion research moved from Chilton to Culham.

The main computer graphics hardware was a Stromberg Carlson SC4020 microfilm recorder at AWRE (also used by Harwell) and later a compatible Benson-Lehner 120 microfilm recorder at Culham. The computer graphics support software primarily came from the SC4020 Users group, Users of Automatic Information and Display Equipment (UAIDE). There was U.K. presence at the UAIDE Conferences from 1964 onwards. Culham produced the GHOST graphics package to support their users.

University Computer Graphics

The Atlas Computer Laboratory (ACL) on the Chilton site was set up in 1963 to provide computing facilities for Harwell, the new Rutherford High Energy Laboratory, and to meet the computing requirements of academic research that were too great for their local university computers. In January 1966 major Regional Computing Centres were established at Edinburgh, Manchester, and London. Together with the Cambridge CAD Centre, they greatly enhanced both the computing and graphics capability of the university sector.

In Manchester, for example, the Computer Graphics Unit (CGU) was set up in 1974 and run by R. Hubbard, previously in G. Butlin’s Computer Aided Engineering Group at Leicester University. Later this became the Manchester Centre for Visualization. An

important feature of the CGU was the remit to support researchers from other departments in the university who wished to use computer graphics in their work. The CGU supported a wide range of hardware and software facilities. Later the staff of CGU became involved in the GKS and PHIGS standards activities. (GKS development is reported later in this article.)

In the London area, early interest in using computer graphics to design and draw maps resulted in the formation of the Experimental Cartographics Unit at the Royal College of Art in January 1966. M. Pitteway, the first Director of the Cripps Computing Centre at Nottingham, was a major researcher in computational geometry. After moving to the new Brunel University near Heathrow in 1967, he, with B. Parslow and R. Elliot-Green, organized three large computer graphics conferences in 1968, 1970, and 1972.¹³ CG70 was the largest with about 1000 attendees. Plenary sessions took place in a large marquee erected in the center of the Brunel campus.

Cambridge had an active CAD Group that locally developed the graphics system the GINO-F (Graphical Input/Output-Fortran version) that became widely used in U.K. universities. A main attraction for the academic engineering community was that GINO was device independent. This made it easy to write an interface for a new device, and there were many different graphics devices in use in the academic community at that time.

The Atlas Computer Laboratory (ACL) provided access to the SC4020 microfilm recorder at Aldermaston from 1963 onwards and installed its own SC4020 in 1967. Together with the Benson-Lehner 120 at Culham, this generated quite an interest in computer animation. In conjunction with the BBC, The Open University, a British public research university with most students studying from off-campus, decided to use computer animation in the launch of its Mathematics Foundation Course M100 in 1970. This course required a significant amount of animation each week. T. Pritchett and J. Lickess had the task of ensuring it was delivered. University computer animators used the ACL's SC4020 and later the FR80 film recorder (manufactured by Information International Incorporated (known as "Triple I") in Los Angeles, USA) in a wide range of disciplines including astrophysics, quantum chemistry, physics, engineering, etc. An example is Ch. Elbeck of Edinburgh University. Elbeck produced at least 12 films (60 mins total) on the topic of Solitons and Bions (Figure 1).¹¹

As the number of universities with Computer Science departments and offering Computer Science (or similar titles) degrees grew, the number of academic



FIGURE 1. ACL's SC4020 microfilm recorder.

departments teaching and researching computer graphics, software, hardware, and theoretical foundations grew. To name a few, this group included the universities of Cambridge, East Anglia, Edinburgh, Leeds, Manchester, Sussex, Swansea, and University College London.

The U.K.'s Road to Graphics Standards

In 1975, ACL merged with the Rutherford High Energy Laboratory and the Appleton Laboratory to become the Rutherford Appleton Laboratory (RAL). The Science Research Center (SRC) became the Science and Engineering Research Council (SERC) and there were several initiatives to improve departmental research facilities in the universities.

One example was the Interactive Computing Facility that upgraded or installed multiuser interactive computer systems that were networked together across more than 20 university engineering departments. The computers involved were two DEC PDP-10s and Prime and GEC multiuser systems (Figure 2).¹¹ In the computer graphics area, engineers made the choice that GINO-F should be the standard computer graphics package used by all the systems, along with a finite elements library and discipline-oriented libraries in control engineering, circuit design, architectural design, electromagnetics, etc.

From 1976 on the emphasis at the Rutherford Appleton Laboratory (RAL) switched to interactive graphics.¹⁴ Several Prime computer systems were installed in university departments and at RAL. All ran GINO-F; they used a mixture of Tektronix, Imlac, and Sigma terminals. It was not a surprise that the U.K. proposed GINO-F as the basis for an international standard.

In addition, the RAL put considerable effort into standards activities with D. Sutcliffe, J. Gallop,



FIGURE 2. An interactive computing facility and its GEC Computers Ltd. minicomputer (on the right – D. Duce).

D. Duce, and F. R. A. Hopgood contributing to the GKS work and Ch. Osland contributing to CGM activities. Following on from the standards activities and collaborating with ICL, RAL implemented GKS. Initially GKS was made available on VAX/VMS and PERQ/PNX and was later installed on other systems including Prime, IBM, and a variety of UNIX systems, including SUN.

From 1978 on, RAL's interest switched to interactive graphics associated with high-powered bitmap graphics (raster) workstations. All were single user systems. Work initially concentrated around the ICL PERQ in collaboration with ICL. The main interest in single user systems at RAL had been to encourage their effective use in the U.K. academic research community, primarily for SERC researchers in engineering (including computer science) and researchers funded by the British government's Alvey Programme.

Early in 1976, the Standards Committee of the British Computer Society proposed that GINO-F¹⁵ (<http://www.chilton-computing.org.uk/inf/alvey/overview.htm>) should be put forward as an ISO standard. ISO/TC97/SC5 had no appropriate Working Group to consider such a request and a Working Party of SC5 organized a meeting in London on 9 February 1977. That meeting resulted in the conclusion that *no existing graphics software was suitable for standardization*. That surprising conclusion roused the community into action.

To work on the standards problem, a Working Group, ISO/TC97/SC5/WG2 Graphics, was set up and held its inaugural meeting in Toronto in August 1977. It was natural that university computing centers and groups (e.g., Cambridge, Leicester, Manchester), industrial or application-oriented institutions (e.g., the CAD Centre), national laboratories (e.g., Rutherford Appleton Laboratory), and commercial companies [e.g., SIGMEX Systems Ltd. (R. Spiers)] would participate in the standards activities. People from these

organizations had extensive expertise not only in system design and implementation but also in application requirements.

U.K. participants played key roles in standards development for many years, including working on the development of GKS, GKS-3D, PHIGS, and PHIGS PLUS, CGM, CGI, language bindings, and conformance testing. At a later stage, the National Computer Centre (NCC) participated and provided a conformance testing service. The GKS implementation developed at Rutherford Appleton Laboratory was awarded an NCC certificate in 1991.

THE EARLY AND PROFILE BUILDING EUROPEAN LIGHTHOUSE ACTIVITIES IN COMPUTER GRAPHICS

Part 1 of this article and the previous section of this Part 2 have recounted the growth of computer graphics in Germany and the U.K. This section looks at the wider community and how it responded to the surprising statement of the ISO Working Party that no existing graphics software package was suitable to be an international standard.

In the period from 1965 to 1975, the active community of experts in CG was distributed worldwide and, nominally, fell into two groups: one with the experts working in academia and R&D institutions and the other consisting of the steadily growing number of experts working in industry as developers, integrators, and/or users of CG technology. The first group was mainly interested in developing new basic concepts and in defining methodologies for computer graphics. They were creating a new discipline within computer science. The second group was more interested in how to successfully develop a market for the new emerging technology, not only as an enabling technology on its own but also as an IT tool to develop innovative, new IT applications. For this group, the highest priority issues were interoperability and integrability: how could they integrate the new technology into existing IT systems in order to address the needs of the emerging, diverse application areas?

The needs can be summarized as follows:

- Develop the fundamentals for CG as a new discipline of computer science.

The fundamentals included new concepts and definitions, new algorithms, new methodologies, and further development of the basic enabling hardware and software technologies and systems.

- › Conceptualize for CG the interoperable system components needed for solutions to the wide scope of CG applications.

These components include, among others, system architectures, I/O-interfaces and devices, graphic data structures, and APIs.

The hard work of defining issues and reaching (or approaching) agreement on the fundamentals and component conceptualization had to be done first. Once done, work on standards could begin.

Work began. It was helped by two European “lighthouse” initiatives in computer graphics: the Seillac I and II workshops (1976 and 1979) for developing fundamental methodologies, and the development of the first standard for CG, the Graphical Kernel System (GKS) which became an ISO standard in 1985. The next sections present and describe these two activities.

The Seillac I and Seillac II Workshops (1976 and 1979)

If you were introduced to computer graphics after, say, 1990, it is probably hard to imagine how little of what we understand as fundamental CG was known and defined in the early years. To better understand the need for and the resulting impact of the two Seillac Workshops,^{16,18} especially in Europe, it is useful to point out the situation we had in computer graphics in 1970–1975.

- › CG was still in an early stage of its development; it was still a “niche-technology” within computer science and ICT-technology; in these early days, CG was not accepted as an integral component of CS.
- › Graphics programming was essentially at the level of assembler programming, customized to the specific hardware being used and not based on any CG software engineering. In other words, there were no operational models, interfaces, or CG-specific programming methods.
- › There was a direct connection between the graphics software and hardware (there was no device independence). Application programs had no structured and functional API between the HW and SW layers.
- › The concept of a generic “workstation” for graphics programming was not yet well defined, conceptualized, or widely accepted.
- › The primary output devices for CG were plotters and vector (calligraphic) displays. Raster display technology was not yet widely available (or affordable), but it was coming and was already expected to gain dominance. See as examples

the developments at Xerox in the USA and ICL (UK) and the Heinrich Hertz Institute (Germany) in Europe.

- › There were discussions, but no agreement, among experts, as to whether GUIs and interaction in CG should be based on pointing (light-pen) or on a cursor (mouse).
- › The design industry had a need to develop CG specific methods for the specification of objects and their geometry, (e.g., 2-D and 3-D curves and surfaces), with associated algorithms and data structures for their transformation and manipulation. In other words, there was (and still is) no agreement about computational geometry dedicated to CG and applications.

There were many big, basic, and fundamental issues to be discussed, developed, solved, and agreed upon by CG experts. The need, relevance, and importance, as well as the resulting implications, are today (some 50 years later!) sometimes difficult to describe, justify, and understand. Here a few examples:

- › How do you specify in generic, common terms a “geometric position?”: Is it a current position (raster) or is it a relative or incremental position (as used by plotters and vector displays)?
- › “Workstation systems” were successfully emerging on the market (like Adage, IDIOM, and later Sun, Silicon Graphics, etc.). What interfaces are needed for programming and for communication with the rest of the IT-system? What should metafile interfaces, data transfer interfaces, device driver interfaces, and communication interfaces look like? Was there a need for more interfaces? How should they be specified?
- › What are the conceptual commonalities and differences among concepts, models, and methods for 2-D and 3-D graphics; for static and for dynamic graphics; and for time-dependent CG [e.g., for graphics in animations and in simulations where $CG = f(t)$]?
- › How do we best use and program with homogeneous coordinates?
- › What are the conceptual commonalities and differences between raster graphics and vector graphics?
- › How do you implement “distributed graphics” in distributed systems (e.g., applications running across networks)?

The above points illustrate the many very basic and fundamental issues that were unresolved and

needed discussion at that time. Concurrently, the two main driving factors—academia and industry—were moving at different speeds: the market use of graphics hardware (plotters, displays, and later workstations) was growing extremely quickly. The educational, training, and research activities in universities were also growing, but at a much lower speed.

As a result, there was a strong demand for standards because of the growing CG market and its need for integration and interoperability of different hardware and systems. But on the other side there was strong demand for the basic concepts, models, and methods needed as underpinnings for the development of standards. Those underpinnings were still missing; they had to come from academia or industrial research laboratories. Those sources were slower in producing these “basics” than industry was in producing the hardware.

The advancements in hardware generated the strong need, particularly in the USA and in Europe, for foundational methodology in computer graphics. From this need emerged the idea of organizing and running workshops to bring the best experts together to discuss, develop, and agree among themselves on definitions, methods, and solutions. B. Herzog (USA) and R. Guedj (France), two very prestigious and well known computer scientists with strong reputations in CG, took the lead in initiating the workshops.

Techniques and tools for computer manipulation of graphical information proliferated those days very rapidly and led to the development of numerous software packages for interactive as well as noninteractive graphics. Their relevance and importance led the expert group IFIP TC 5 “Computers in Industry” to set up a new committee to concentrate on creating a methodology around which a standard could later be built. Herzog and Guedj used the opportunity of this new committee to push for a workshop on “Methodology for Computer Graphics.” The workshop was held at Seillac, France, on 23–26 May 1976, and is known as the “Seillac I Workshop.”¹⁶ This workshop was planned to study basic issues and sought to clarify the underlying concepts to achieve a better understanding of graphics systems. This understanding was needed before starting the work on related standards.

The main goals of the workshop were to work on a better understanding of the field and to agree on a conceptual framework and on a common definition of many of the frequently employed terms. A group of European experts deeply involved and working in computer graphics was nominated by IFIP TC 5 WG 5.2 (CAD) to organize the Seillac I Workshop. The chairman of this group was Richard Guedj from France; the

other members of the group were K. Bo (NOR), J. L. Encarnacao (GER), G. Hermann (HUN), B. Hopgood (U.K.), A. Lemaire (F), M. Lucas (F), Th. Sancha (U.K.), and H. Tucker (DEN). This group decided to invite 16 additional experts from different countries to participate and contribute to the workshop, including from the USA and others. They included leading experts in CG at the time like P. Bono, J. Foley, B. Herzog, W. Newman, A. Shaw, and A. van Dam.

A Position Paper From Germany for Seillac I

The German constituency of experts working in CG was very interested in presenting and discussing their own ideas, concepts, and methodologies at the Seillac I workshop. These topics had been under discussion since the early 1970s either in the GI FA 4.1, the German Special Interest Group in CG, or in the group in the German standardization body, the DIN working group on graphics standards.

Therefore, a group of experts in Germany, which I chaired together with G. Nees (who worked at Siemens AG), started working on a position paper to be presented and discussed at the Seillac I workshop in 1976. The paper was titled “Recommendations on Methodology in Computer Graphics.”¹⁷ Its content was the result of cooperation between scientists from several institutions in Germany dealing with computer graphics, including developers and users of graphics systems coming from academia and from industry.

The goal presented in the article was to establish a consistent approach to the methodology for defining, describing, designing, and using graphics systems. A graphics system should be defined in a way general enough to support a wide variety of users and it should also be easily understood by programmers and users. To reach the desired goal of such a device-independent, general-purpose system, the article proposed the following

- › The graphics functions to be defined include only the construction, editing, and manipulation of pictures (i.e., no picture analysis).
- › A picture is generated from vector and/or text elements (no grayscale pictures). (Our context was graphical output on vector/character displays.)
- › Only those graphics peripheral devices that are suitable for a general-purpose system should be considered.
- › The definition of graphical functions that represent the user interface should reflect the expected frequency of occurrence of the operational device

types (e.g., the hardware of the most frequently used device types should be utilized as effectively as possible).

Our team proposed to concentrate on device independence, defined as the ability to use the same application program on a wide variety of devices. Such device independence should contribute to the ability to produce graphical data on one computer and then output it successively or simultaneously to different graphics output devices (also using external intermediate storage). Simultaneous output on different devices was presented as being important when it is necessary to work with different picture sections (e.g., displaying a general view and some detailed view of a subregion of the same picture). Additionally, it was considered to be very important to have, in addition to output-device independence, also input-device independence.

The article presented and discussed how device independence could be realized by using logical input devices and having them assigned to physical input devices. The basic idea in designing a graphics system, as presented in the paper¹⁷ and discussed at the Seillac I workshop, was to split the system into device-dependent and device-independent parts, and hence to have graphical input/output completely separated from the user's program (Figure 3). The basis of such a device-independent graphics system was submitted, presented, and very intensively discussed at the workshop as being one possible basis to develop a methodology for computer graphics. This architectural separation of graphics I/O and user's application program was an important conceptual breakthrough.

OUTCOMES OF SEILLAC I AND SEILLAC II

The important outcomes and results of the Seillac Workshops were the agreement between the experts on definitions and concepts for, among many others, the following:

- › The goal was to develop a "Methodology in Computer Graphics," not to primarily make specific recommendations for graphic standards.
 - › The graphics system is, from a system point of view, composed of five components: input devices (mouse, data tablet, keyboard, etc.); graphics processing unit [(CPU) model dynamics, interaction, rendering]; memory (model, display list, viewing), frame buffer (array of pixels, standard memory, depth, resolution), and output devices.
 - › Agreement to differentiate between two classes of pictures: those pictures representing an abstraction of reality, and those pictures that depict reality itself.
 - › Agreement to consider input and output devices as "logical I/O devices" (virtual devices) to achieve device independence; the objective for the future should be "portability" of graphics software.
 - › Agreement to separate functions supporting modeling (description of objects) and those for viewing (for the generation of pictures).
 - › Agreement that applications should work in a world coordinate system, to be converted to the device coordinate system by viewing transformations.
 - › Agreement that, to allow for picture manipulation, pictures should be structured in modifiable segments stored in a display file.
- An important recommendation that came out of Seillac was to make a clear distinction between "graphics subsystem" (to process picture descriptive data) and "modeling subsystem" (for the viewing process). The workshop recommended the specification of both subsystems as important future work in CG.
- One of the additional outcomes of the Seillac I workshop was the agreement among the participants that much more effort should go into the area of "methodology of interaction," which would include interactive graphics systems. Based on this, the IFIP WG 5.2 began planning a second workshop in Seillac to address this topic. This workshop took place in May 1979, again with R. Guedj as the chair. The goal was to discuss open issues and prepare new ways of looking at interactive systems, their design, and implementation. The results are reported in Guedj et al.¹⁸
- Based on the results of the Seillac I workshop, several groups, especially in Europe and in the USA, then started R&D and standardization activities, mainly in two directions:
- › The more academia- and R&D-oriented groups of experts started developing several specific research agendas to conceptualize and develop basic concepts and methodologies for CG.
 - › The more market- and industry-oriented groups of experts started or reinforced their work on developing graphic standards based on the understandings, terminologies, and concepts agreed on at the workshop. In Germany, the responsible DIN group continued to advocate for GKS to be the first ISO and DIN standard for computer graphics.

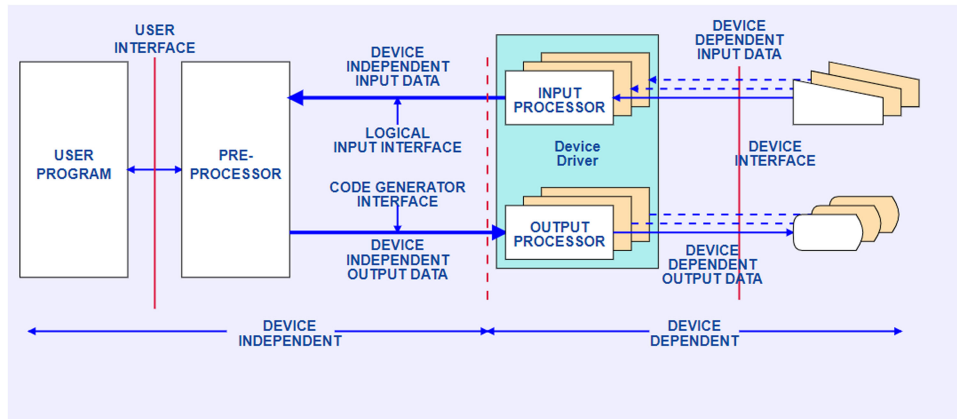


FIGURE 3. Separation between user-program and graphical input–output.¹⁹

GKS—GRAPHICS KERNEL SYSTEM: THE FIRST ISO GRAPHICS STANDARD

In the early 1970s, the large proliferation of CG applications generated a set of activities on standards for computer graphics. Among those were GINO and Ghost in the U.K., IDIGS in Norway, GSPC in the USA, and GMB and GKS in Germany. At the time, the two strongest activities on standards for graphics were GSPC, the SIGGRAPH Core standard proposal,¹⁹ and the German GKS standard proposal.²⁰ In the beginning, a big difference between the approaches and concepts was that the SIGGRAPH Core was strongly 3-D oriented and GKS basically 2-D. The groups involved saw in the results of Seillac I the confirmation of their efforts and of the emerging concepts on which they were basing their work. All now felt strongly motivated to continue and even intensify their activities to use and further develop the results to specify standards for computer graphics.

Several of the main concepts embodied in GKS (Figure 4) were, at the time, breakthroughs and had a major impact on the further development of computer graphics as a technology, as a tool, and in applications. They included:

- › The “Workstation Concept.” The programming is based on the functionality of an abstract machine and not on the specific characteristics and properties of the particular graphics system and I/O devices being used.
- › The description of pictures and their geometry is done in GKS in “normalized coordinates” that are used when programming. In the final stage of the specification of the GKS standard, the concept of a “current position” was introduced in opposition to the relative coordinates in use at

the time. This was done in order to easily integrate with raster technology, which was rapidly being adopted across the industry.

- › The specification of GKS was initially a “2-D standard,” but in the final stage of the development of the specification of GKS, it was extended to be “also a 3-D standard.”
- › Hardware peripherals are programmed as “abstract I/O devices.” Interactive dialogs are based on a formal dialog specification and application-specific programming.
- › The communication with the I/O devices being used is programmed based on a standardized driver interface, called Computer Graphics Interface (CGI).
- › The communication of data between the abstract workstation and output-only graphics devices is programmed based on an external data interface called the Computer Graphics Metafile (CGM).

In Germany, after the Seillac workshops, the standards organization DIN in its working group on Graphics Standards intensified their activities on the development of GKS. Their target was to submit it as soon as possible to the responsible ISO group (the ISO/TC 97/SC 5/WG 2) as the proposal for an international graphics standard. At the time I held the position of chairman of this DIN group (the vice-chairman was G. Nees from Siemens AG) and as such I became the DIN representative to the ISO group.

The strategic intention of the DIN group, being pushed by industry and driving these activities, was to avoid different, divergent, and incompatible graphics standards. This was successfully achieved and in 1985, almost 10 years after the Seillac I workshop, GKS was officially announced as the ISO Standard IS 7942 and published as the first ISO Graphics Standard.^{19,20,21,22,23,25}

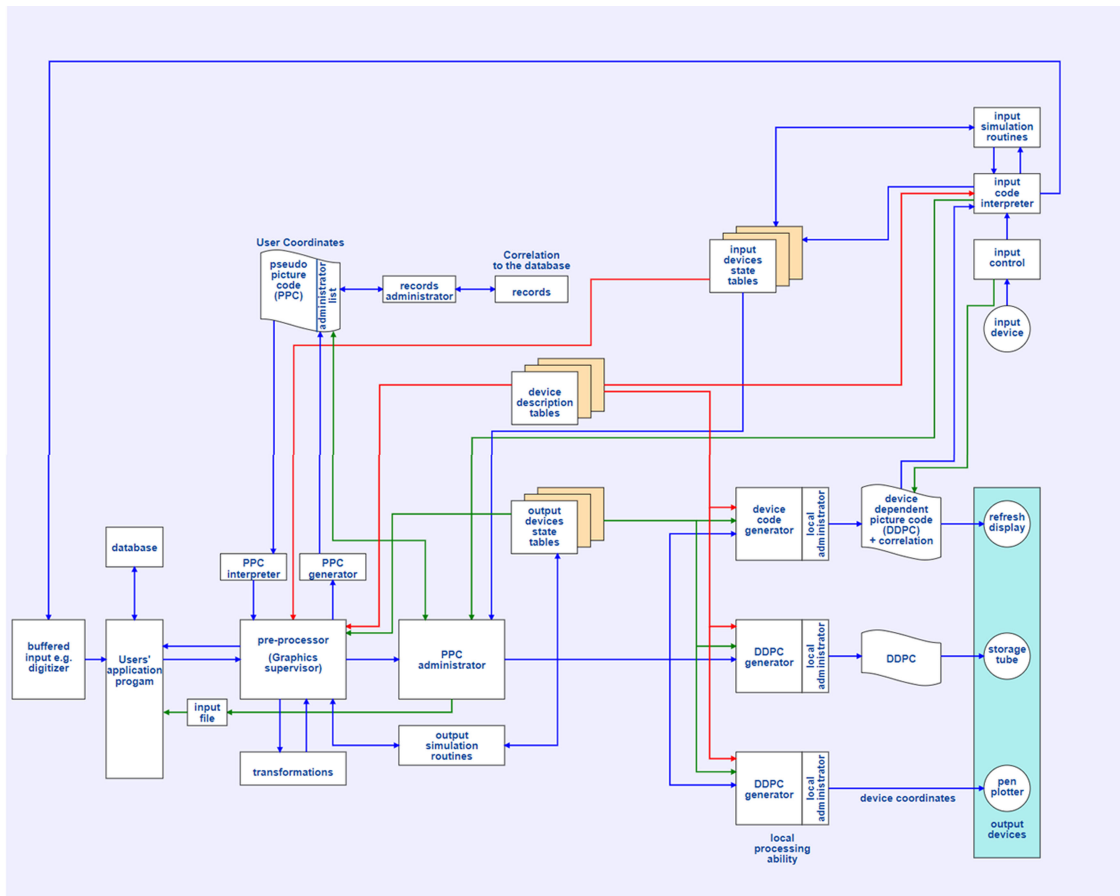


FIGURE 4. Concept for a device independent graphics system. ^{17,24}

GKS has had a lasting impact on the further evolution of computer graphics in Europe, especially in the education and training of experts in the programming of graphics systems. It has also had impact in the subsequent research in all of the system and software engineering aspects of computer graphics, its programming, and in the development of applications and of the related APIs. Several graphics languages that emerged later and were very prominent on the market strongly benefited from GKS. ^{24,26}

The original early concept of GKS was developed in Germany not only in my group in Darmstadt but also with important contributions from experts coming from several universities, research institutions, and industry in the country. In the final standardization phase, the work was an international effort under the ISO umbrella with significant contributions from several other European countries and specially from ANSI in the USA.

The German DIN WG was a quite large group that worked for almost 10 years on the development of GKS and related pilot-implementations. I cannot here name all of the DIN experts individually and describe their

involvement and contributions. Nevertheless, the names from a few that were personally especially deeply involved and made major contributions with a big impact in the GKS development, are listed here to show a deep appreciation for their engagement and for their contributions to the success of GKS as the first ISO graphics standard. Among the many others were R. Eckert, P. Egloff, G. Enderle, E. Hörbst, K. Kansy, G. Nees, G. Pfaff, S. Prester, J. Rix, and P. Wißkirchen. I name these few as representatives for all those who in Germany at the time participated in and contributed to the development and pilot-implementations of GKS.

SUMMARY AND CONCLUSION

The “Origins of Computer Graphics in Europe” may be seen as starting around 1965 with a quite small group of experts doing some early, pioneering R&D in this area in countries like France, Germany, The Netherlands, Scandinavia, and the U.K., and ending with the ISO announcement, publication, and dissemination of GKS in 1985.

These were a very interesting, successful, and extremely motivating 20 years. The following ten years (until around 1995) were needed to develop, establish, consolidate, and stabilize *computer graphics as a discipline of computer science and of information technology* based on and building upon the developments and results achieved up till 1985. These 30 years (1965 to 1995) are unforgettable for everyone involved in contributing to this success story, *the origins, the establishment, and the evolution of computer graphics in Europe*.

In summary, a key lesson is that, if, in the early 1960s, you start developing and establishing a “new, emerging technology” like “computer graphics” in academia and in the European market, you need local availability of certain “ingredients”:

- › The provision of professor and research positions in academia, so that you can teach and train the new experts for the area.
- › The provision of platforms for conferences, workshops, and seminars, where these new experts can present and communicate their results and implement their professional networking activities.
- › The establishment of the corresponding professional societies to organize and structure the new field with the steadily increasing number of new experts.
- › Finally, it also requires a few “lighthouse” activities: events and research and innovation (R&I) projects that help in developing and raising the profile for the discipline as such. The lighthouse activities help in developing some dynamics for the related community building process and are themselves also strong motivation for the experts to get involved, to participate, and to contribute.

All of the above ingredients are needed to move the evolution of the “new, emerging technology” forward, and to make sure that it becomes well established, consolidated, integrated, and accepted in academia and by industry and users in the targeted market. As reported in this article, between 1965 and 1995 there were highly focused, though geographically distributed, efforts to define and develop these necessary ingredients. That computer graphics is so successful today in Europe is a tribute to the many people strongly engaged in the successful development of the foundational ingredients and the many more who have followed and successfully built upon them.

This Part 2 of the article ends with a large list of references the reader may use to access further information and more details on the 30 years of successful evolution and establishment of computer graphics in Europe.

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I wish to dedicate Part 2 of this article to all participants of the two Seillac Workshops, especially to R. Guedj, who initiated, coordinated, and moderated them in a very successful way. He was the leader and “the father” of this initiative and the results laid the groundwork for computer graphics as a discipline and for its future success in Europe. This is a lasting legacy of R. Guedj; he passed away in 2022.

The “Origins of CG in the U.K.” section is based on personal notes¹⁰ written and made available to me by two British colleagues, F. R. A. Hopgood and D. Duce, two very prestigious and most prominent pioneers and experts in computer graphics worldwide and very important driving forces for computer graphics in the U.K. and in Europe. I wish to acknowledge here their contribution to this article and to thank them for their very helpful support and cooperation.

By describing in this article my view and personal knowledge on the “Origins of Computer Graphics in Europe,” I also partly describe my professional lifework,^{3,4} very strongly influenced, and shaped by my Ph.D. and initial research in computer graphics in Berlin from 1968 to 1972.¹ Therefore, I wish to dedicate the overall paper to my teacher and Ph.D. advisor (in German it is called the “Doktorvater”), who has been since then “the” example for my professional life, Professor Wolfgang Giloi (1930–2009). He was a great personality, brilliant, and very far-seeing. He was for me personally also the most important initiator and “intellectual father” of my participation in and contributions to these “Origins.”

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JOSÉ L. ENCARNÇÃO is a professor of computer science with Technische Universität Darmstadt (professor emer.) and Fraunhofer Institute for Computer Graphics IGD (retired director), 64289, Darmstadt, Germany. Contact him at jl_encarnacao@t-online.de.

Contact department editor Mary C. Whitton at mcwhitton@gmail.com or department editor Dave Kasik at dave.kasik@gmail.com or department editor Chris Johnson at crj@sci.utah.edu.