Vignettes of Sweden's Computer Graphics History

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This article recounts selected historical events in the computer graphics field in Sweden, ranging from hardware construction to human–computer interaction. Particularly noteworthy are the industrial developments of semigraphical interfaces for improved man–machine communication, and the patented invention of a color graphics system by Håkan Lans, which gave rise to several court cases.

Throughout history, people have used different graphical means of expression. Some ancient examples are the Swedish petroglyphs in Tanumshede and Nämforsen (see Figure 1). Although visual means of expression are as old as humans themselves, it was the start of the computer era that elevated the importance of visual information to entirely new levels. As one of the core technologies enabling visual presentation of, and intuitive interaction with, all sorts of data and information, computer graphics can be regarded as the catalyst for this development. What's more, customer demand for faster computer graphics and advanced GUIs (in particular, 3D graphics and games) has been a driving force behind the rapid development of the computing power and graphics capabilities in today's computers.

In this article, we present several major early achievements in Sweden related to the rapid development of computer graphics. Table 1 lists important milestones in Swedish computer graphics research. In subsequent sections, we sketch nine of the major events in more detail. These sketches include events in both industry (applications, research, patents, and products) and academia (research and teaching). We have based our presentation on a combination of literature studies, personal experiences, interviews, and email correspondence. Some material has been presented previously in a Swedish report by Ulf Stenlund;[12] in addition, sources with a specific focus on Scandinavian research efforts[1,8,9,13] and teaching activities are available.[14]

BESK

In 1948, Sweden initiated the National Committee on Mathematical Machines (MMN) to address the nation's need for calculating machines. Together with a group of skilled engineers, Eric Stemme created the first Swedish electronic computer called the Binary Electronic Sequence Calculator, or BESK for short, which was completed in Stockholm in 1953. Equipped with 2,400 vacuum tubes, it had a cycle time of 14 microseconds with 4 cycles for carrying out an addition operation. Reportedly, BESK, which found extensive usage for the computation of weather forecasts, was able to deliver a 3-day forecast in one hour of computation time, whereas it took the ENIAC, in the US, 24 hours to compute a 24-hour forecast.[15] Interestingly, from a graphics point of view, BESK was equipped with a display for curve drawing on film in 1954, thereby enabling the transformation of numbers into images.[1] This equipment can still be seen in Stockholm's National Museum of Science and Technology. A total of 11 computers, which were essentially BESK replicas, were later built and delivered by the Facit company, which had hired Stemme after the MMN committee disbanded in the mid-1950s.[16]

An early application

As early as 1962, engineer Bo Lindestam was faced with an applications problem: how to represent parts of the human body for medical purposes. Lindestam had at his disposal an ALWAC III-E computer. (*ALWAC* derived from *A*xel *L*eonard *W*enner-Gren

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*A*utomatic *C*omputer; the computer was built by Research Logistics, a California company that Wenner-Gren—originally from Sweden—had bought in 1952.) At any rate, the ALWAC was a slow vacuum-tube computer—a simple multiplication could take 50 ms. However, the ALWAC did have a unique feature: its peculiar paged memory layout could be utilized for work in three dimensions. Accordingly, by directly addressing the memory in an appropriate way and using some software tools he had developed, Lindestam could make transformations of matrices as well as convolutions and summaries of data. His computations, of course, were very time-consuming because the computer was so slow (Bo Lindestam, personal communication, 2005).

In Lindestam's application, he assigned each examined part of the body its own XYZ-system. The results were output onto paper with marks for the XY-coordinates, one sheet per Z coordinate, with numbers printed on the appropriate mark. By examining the numbers, medical experts could draw meaningful conclusions. Lindestam reported that his application was primarily a theoretical tool, as neither medical science nor computer technology was sufficiently advanced for what he envisioned until at least 20 years later.

Hertz's ink jet plotter

During the 1960s, at Lund University, professor Helmut Hertz developed a color graphics printer, achieving a working prototype by 1970. The technology made it possible to shoot tiny droplets of ink onto a piece of paper attached to a rotating cylinder.[17]

Apart from the innovative technology, which was a major breakthrough in itself, the possibility of working with color raster graphics at a 125-dpi resolution at that time was astonishing. In collaboration with Hertz, Mikael Jern developed COLOR, rasterization software that was unique during the 1970s. Hertz and Jern sold both the color printer and the software to the US company Applicon in 1977.[1] Jern moved to Boston and worked for Applicon over the next two years to improve the rasterization techniques he had originally developed. Unfortunately, Applicon was unwilling to develop the system further to enable users to directly produce color images on computer displays then coming onto the market. Consequently, Jern founded his own company UNIRAS (*Uni*versal *Ra*ster *S*ystem) together with a Danish colleague, Jan G. Knudsen. Within a few years, UNIRAS was well established and offered software products for presentation graphics and visual data analysis, and the company was a leader in graphics software development for more than 20 years. As a result of its success, UNIRAS was acquired by AVS (Advanced Visual Systems) in 1993, and Jern continued to work for the merged company as director of research for the next five years.

Since 1999, Jern has been a professor at Linköping University where he works in the Norrköping Visualization and Interaction Studio. Jern was honored as a pioneer of computer graphics at SIGGRAPH 1993 on the basis of his early ground-breaking raster graphics research.

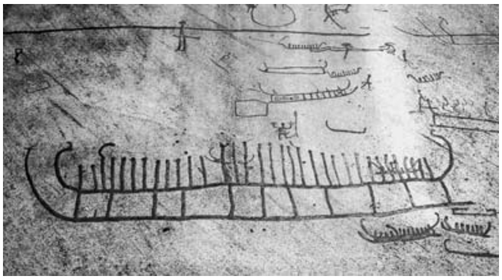

Figure 1. A petroglyph of a bronze age ship in Tanumshede. (Courtesy of Vitlycke Museum.)

Semigraphical interfaces

In 1975, engineer Jan-Erik Lundström from ASEA (Allmänna Svenska Elektriska Aktiebolaget [General Swedish Electrical Limited Company]) went to the US seeking a suitable visual display terminal for color presentations. Unfortunately, he found nothing suitable for the company's needs. Instead, in 1976, ASEA arranged with Swedish Radio AB (SRA) that SRA would manufacture a semigraphical terminal according to ASEA specifications. The terminal was called SRA Semigraf.

Figure 3 shows the SRA Semigraf 212 as it appeared in a 1976 brochure. The SRA Semigraf 212 was a color display system for graphics and alphanumerics, and the terminal included special hardware for drawing curves. The brochure states that "The SEMIGRAF 212 is designed to be used with computer based systems for maximum 'man-machine' communication." ASEA used the terminals with their SINDAC systems, large supervisory control and data acquisition systems designed primarily for power plants and power distribution control.

The SINDAC systems were also used in the process industry. Mönsterås Bruk, for example, was a large pulp mill in southern Sweden with as many as 14 of ASEA's SINDAC systems in operation in the early 1980s. The economic

Table 1. Major Swedish milestones related to computer graphics.

Year	Milestone
1954	The early Swedish computer BESK (Binary Electronic Sequence Calculator) was equipped with a special device for curve drawing on film.[1]
1962	Bo Lindestam used an ALWAC computer and 3D graphics computations to produce digital representations on sheets of paper of human body parts for medical purposes.
1968	Torleiv Orhaug and his research group at Försvarets forskningsanstalt [Swedish Defense Research Agency] started work on image digitizing and processing.[2]
1970	The high resolution color ink jet plotter developed by Hertz and his research team at Lund stood ready for use.[1]
1971	Håkan Lans developed the first mass produced pointing device called the HIpad (see Figure 2) made by Houston Instruments.[3]
1976	SIGRAD (Swedish Computer Graphics Association) was founded by Lars Kjelldahl.[1]
1976	The SRA Semigraf 212 color display system for graphics and alphanumerics was designed.
1978	The Luxor ABC 80 featuring semigraphical signs was introduced, which can be considered the start of the Swedish personal computer market.[4]
1979	Sven Torbjörn Lagervall and Noel Clark discovered Ferroelectric Liquid Crystals (FLC), which made possible the production of high-resolution flat video displays.
1979	Håkan Lans filed the patent for a data processing system and apparatus for color graphics display. He received US Patent #4,303,986 in 1981.
1980	The company UNIRAS was founded to develop rasterization software for devices such as the Hertz ink jet plotter.[1]
1980	ASEA presented the Tesselator information system for improved man-machine communication.[5]
1980	Lars Kjelldahl offered the first computer graphics course at Kungliga Tekniska Högskolan (KTH) in Stockholm (Lars Kjelldahl, personal communication, 2005).
1981	The Scandinavian UTOPIA project was started, which utilized workers with domain knowledge in the design process in innovative ways.[6]
1983	Luxor presented the computer ABC 806, which, together with the color display ABC 812, presented color graphics with a resolution of 512 × 240 pixels using 4 colors, and 256 × 240 pixels using 8 colors.[7]
1985	A special issue, "Arctic views on computer graphics," appeared in the journal *Computers & Graphics*.[8] Another special issue with a similar theme appeared 10 years later.[9]
1985	Björn Gudmunsson published the first Swedish graphics textbook entitled *Datorgrafik*.[10]
1985	The company Real-Time Graphics is started on Jan-Erik Lundström's initiative. In 1988, its software product called EyesCream for graphical interfaces was launched (Jan-Erik Lundström, personal communication, 2005).
1986	The software product Graph-in-the-Box, with its promise of "instant graphs in virtually any application," was released by Pierre Lingheim and his company. In May 1988, 150,000 copies had been sold.
1991	Digital Illusions was founded by the three young Swedes: Fredrik Liliegren, Andreas Axelsson, and Olof Gustavsson. The following year their first two games, Pinball Dreams and Pinball Fantasies, were released for the Commodore Amiga with enormous success.
1991	The first version of the Distributed Interactive Virtual Environment (DIVE) developed at the Swedish Institute of Computer Science appeared.[11]

lifetime of the SINDAC systems proved to be longer than for the terminals. This led ASEA to decide to replace the Semigraf terminals with personal computers on which Mönsterås Bruk's mill personnel emulated the terminals using DOS software. The SRA Semigraf display was limited to 36 or 48 rows of symbols in which each symbol consisted of either 8 × 6 or 8 × 8 pixels. However, several engineers, including Lundström, in ASEA's Development Department for Electronics felt hampered by the Semigraf's symbol size. They wanted to be able to freely mix symbol sizes as well as arbitrarily decide where on the screen a symbol could be displayed. By using patterns from a book on cross-stitching to illustrate their idea, the engineers convinced ASEA management to fund the project. The result of the development, a graphics system called Tesselator, was launched on the market in 1980.[5]

The smallest part of a symbol, known as a *Tessel*, was composed of 3 × 3 pixels. The symbols were defined in a symbol table and could be built in any size. Furthermore, each symbol had a definition point that could be assigned to an arbitrary location on the screen.

A useful feature of the Tesselator was its inherent object orientation. A particular symbol needed to be described only once and could be reused wherever needed. The first application utilizing the Tesselator was in power distribution control. Figure 4 shows some representative images from a power distribution control application.

To enter into smaller industrial applications, ASEA decided to develop products based on its general data system DS100, which had been mainly used for large ASEA projects. The resulting product line was called ASEA Master, and the Tesselator was packaged as part of the operator station, the ASEA Master View. The successor to the ASEA Master is the ABB 800 system, which is today one of the world's leading process control systems. (ASEA merged with Swiss BBC Brown Boveri in 1988 to form the multinational corporation Asea Brown Boveri [ABB]). Unfortunately, this very expensive product transformation resulted in ASEA's cutting basic Tesselator development funding. This situation, together with restrictions resulting from ASEA's rules governing what components were allowed to be used (because of quality and production considerations) in further developing the Tesselator caused Lundström to leave ASEA.

In 1985, Lundström and his new employer, Westermo Teleindustri AB, started a new company called Real Time Graphics. The basic business concept of RTG was to replace text-based information with more advanced computer graphics solutions, still with a semigraphical approach, but now with the smallest component being one pixel (Jan-Erik Lundström, personal communication, 2005). The software was named EyesCream, and in fact, the company itself was soon renamed to EyesCream.

Figure 5 shows an airline reservation system, an example of what this small company was able to accomplish in 1988, when the software was launched. In this system, passengers could clearly tell which seats were available and choose their preferred seats online. Unfortunately, due to a liquidity crisis, EyesCream went bankrupt in 2002, although parts of the company still exist.

Luxor's computers

In 1978, electronics and television set manufacturer Luxor AB, founded in 1923, introduced its ABC 80 (*A*dvanced *B*asic *C*omputer for the *80*s) to the market.[4] The ABC 80 represented the first serial production of a Swedish computer. The first batch of 7,000 computers sold for 6,900 Swedish crowns, tax excluded. The ABC 80 became very popular in Swedish schools. It was equipped with 16 Kbytes of ROM, which included a Basic interpreter, and many of us in school at the time remember our first programming lessons in which we wrote small Basic programs using row numbers and lots of GOTOs.

Although the ABC 80 lacked high-resolution graphics, this machine could be used, through semigraphical symbols, for graphical presentations. The semigraphical symbols were accessed by adding 128 to the normal ASCII codes given in the interval 32-127. Interestingly, the symbols' appearance was achieved by filling "dots" in a 2×3 grid, effectively resulting in a graphics resolution of 80×75 rather big "pixels." In fact, there was also a special graphics mode called setdot-graphics, in which, from a user's viewpoint, it appeared that these "pixels" could be addressed individually.

A few years later, in 1981, Luxor launched the ABC 800 in an effort to appeal to a wider market for its computers. This machine supported a graphics mode with a 240×240–pixel resolution. The subsequent 1983 model, the ABC 806 (see Figure 6), featured high-resolution color graphics in conjunction with a color monitor (the ABC 812). This machine was equipped with a 128-Kbyte graphics memory that could store up to four different images separately, which made instant image swapping possible. However, part of the graphics memory could also be used for storing

Figure 2. Håkan Lans' pointing device, the Houston Instrument HIpad, from the 1970s. Lans was able to create an interactive color graphics application by rebuilding a color TV into a color display reacting directly to the commands issued from the digitizer board (Håkan Lans, personal communication, 23 Jan. 2007).

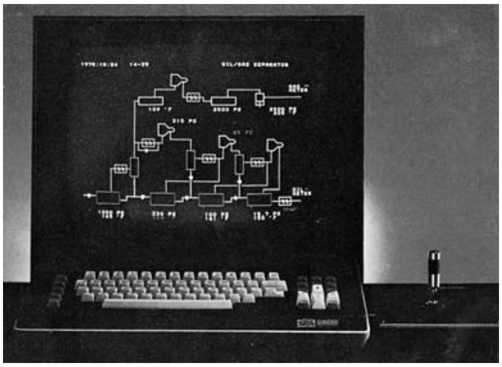

Figure 3. The SRA Semigraf display system as depicted in a 1976 ASEA company brochure.

program code or other data. If, for example, two images were stored, with a resolution of 240 × 240 pixels using four colors, chosen from a palette of eight colors, there was room left for 66 Kbytes of data. In other graphics modes on the ABC 806, images with a resolution of 512 × 240 pixels using four colors, or images with 256 × 240 pixels using eight colors, were possible.[7] The price for the ABC 806 in 1983 was 11,400 Swedish crowns, excluding tax.

Despite the promise of the ABC 806, the Luxor company began experiencing significant financial problems. First, the state took over the company's ownership from 1979 to 1984. Then in 1984, the Finnish company Nokia acquired Luxor and terminated production of the ABC line in 1986.[4]

Color graphics system

Håkan Lans (see Figure 7) is a well-known Swedish inventor who experimented early with color graphics displays such as that in Figure 2. In early 1979, Lans submitted a patent application, "Data processing system and apparatus for color graphics display," and in 1981 received US patent #4,303,986.[18] The patent describes a system that offers fast, efficient random access to a color picture memory, which makes high image update rates possible on a CRT monitor, for example, or on any other suitable display device. The disclosed system consisted of a video memory controller with an internal memory communicating with a host computer to produce synchronized color graphics signals for a display device.

Initially, because of a seeming lack of apparent applications, the patent drew little attention. When the first personal computers arrived on the market, however, Lans's technology became highly interesting and, as it turned out, hard to circumvent. Therefore, in 1988, IBM voluntarily acknowledged Lans's patent and signed a license contract with one of Lans's companies, Uniboard AB, which held the patent rights. Some years later, Japanese manufacturer Hitachi acknowledged the patent and signed a license agreement. However, Dell and Hewlett-Packard refused to pay license fees, which resulted in a truly unfortunate lawsuit on behalf of Lans.

As it happened, before the agreement with IBM was signed, Lans had transferred the patent rights to Uniboard. Despite this fact, the legal firm representing Lans decided that Lans personally, not Uniboard, would be the named plaintiff to sue the computer companies. This was a huge mistake: rather than dealing with the patent infringement issue, the legal process focused on who was the patent's rightful owner, and on the difference between the plaintiff and the patentee. This minor technicality—that the complaints had been filed by the wrong person [or entity]—was crucial to the case's outcome. In a 6

Figure 4. Representative Tesselator images emulated by TessEm software on a modern PC. Note the different symbol sizes. The images are displayed on flat screens in this photo because the product is available now only by emulation. (Courtesy of Newcon Data AB.)

September 2001 judgment, the court declared that Lans personally had to pay essentially all lawyer costs for both parties, estimated to exceed 100 million Swedish crowns—this, despite the fact that, according to Lans, it was his own lawyers who had made the disastrous mistake.[19]

In January 2002, Lans and a new set of lawyers filed a motion for reconsideration of the burden imposed on him to pay all attorney fees. The process did not get under way, however, until the then Swedish Minister for Industry and Trade, Leif Pagrotsky, and a few other European Union parliamentarians, expressed concerns about the rights of foreign inventors in the US. It was not until December 2004, almost three years later, that the case went to court; again, the outcome was not in Lans's favor. On 23 June 2005, the new judgment was issued, resulting in Lans's again being obliged to pay both parties' attorney fees. Political scientist Erik Moberg has speculated that the case against Lans is a judicial crime.[3,19,20]

Ultimately, partly supported by money from the Swedish state, Lans went before the United States Court of Appeals for the Federal Circuit.[21] Surprisingly, the court settled the case in less than a week and, in the 11 October 2006 judgment, granted none of the relief Lans sought. Apart from his personal losses, these legal maneuvers undoubtedly drained time and energy from Lans that otherwise could have been devoted to new inventions.

Cooperative design

Computer graphics and human-computer interaction design methods have always been tightly interwoven. Not surprisingly, several computer graphics pioneers were involved in helping to lay the groundwork for effective user interface design during the 1970s.[22] An early Scandinavian effort is the seminal UTOPIA (*U*tbildning, *t*eknik *o*ch *p*roduct *i* *a*rbetskvalitetsperspektiv [Training, Technology, and Product in Quality of Work Perspective]) project developed between 1981 and 1986. The project was initiated by the NGU (Nordic labor unions for graphic workers) in 1980, and led by Pelle Ehn and Susanne Bodker with the goal of designing new computer-based tools for page makeup and image processing in light of emerging workstation technology featuring graphics capabilities.[6]

UTOPIA emphasized mutual learning between graphic workers (the users), computer scientists, and social researchers, and utilized the workers' domain knowledge and skills, including work- and environment-related requirements. A technology laboratory was established to simulate work processes, using innovative simulation equipment including various mock-ups, prototypes, and a graphics workstation.

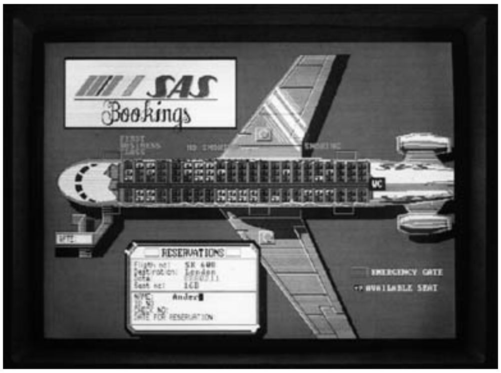

Figure 5. An airline reservation system based on EyesCream. (Courtesy of Jan-Erik Lundström, Penny Futureyes AB.)

In the end, UTOPIA's most interesting outcome was a new methodology known as cooperative design, ''for involvement of end users together with interface designers and program developers on equal footing in computer application projects.''[6] Today, this methodology is also known as the Scandinavian school of IT design. Furthermore, the concept of supporting and strengthening the user/worker relationship in the design process has evolved into an active research area commonly referred to as participatory design.

The well-known UTOPIA project originated from several earlier, 1970s Scandinavian proj-

Figure 6. The Luxor ABC 806 computer. (Courtesy of Rune's PC-Museum; http://www.pc-museum.com.)

Figure 7. Håkan Lans, Swedish inventor of modern color graphics memory (c. 2002).

ects. These included, for example, Sweden's DEMOS project on trade unions, industrial democracy, and computers; and Denmark's DUE (*D*emokrati, *U*dvikling og *E*DB [Democracy, Development, and Electronic Data Processing]) project on democracy, education, and computer-based systems.[23]

DIVE

An initial effort in creating shared 3D synthetic environments at the Swedish Institute of Computer Science (SICS) resulted in the first version of The Distributed Interactive Virtual Environment (DIVE) in 1991. It was developed by Olof Hagsand and his colleagues at SICS.[11,24]

DIVE can be regarded as a multi-user virtual reality system based on a peer-to-peer approach using Internet protocol (IP) multicast communication, and it is because of its strong focus on flexibility, human-human communication, interaction, collaboration, and sharing that DIVE stood out from other virtual reality systems.[11] In DIVE, distributed applications are created in which multiple users collaborate through interaction. Present simultaneously within the same shared 3D scene, users can see each other, and meet and speak with each other. Each user, while navigating in the environment, is (optionally) represented by a ''body-icon'' or avatar (see Figure 8). Each user sees the same things and hears the same sounds, although from a different location in the shared virtual world.[11]

Figure 8. A screen shot from a DIVE application showing an avatar. (Courtesy Swedish Institute of Computer Science.)

DIVE was never meant to be a commercial platform, but rather a research tool, and it has been used in several research sites around the world for prototyping and evaluation of virtual environments.

Higher education

Associate professor Lars Kjelldahl has worked in the computer graphics field since 1970. He founded the national special interest group SIGRAD in 1976[1,25] and two years later defended his PhD thesis in computer graphics.[9] Kjelldahl offered the first computer graphics course at Kungliga Tekniska Högskolan (Royal Institute of Technology) in Stockholm in 1980 (L. Kjelldahl, personal communication, 2005). At that time, *Principles of Interactive Computer Graphics* by William Newman and Robert Sproull was considered the standard textbook (McGraw-Hill, originally published in 1973; the second edition appeared in 1979).[26]

From a Swedish perspective, it is worth mentioning that the first Swedish textbook on computer graphics, by Björn Gudmundsson, arrived in 1985.[10] Despite its age, this book presents fundamentals for LCD displays. Another noteworthy detail is that the book consistently used the term ''rat'' instead of ''computer mouse.'' The terminology change was deliberate, according to Kjelldahl, in an (unsuccessful) attempt to replace the term ''mouse'' because the latter could potentially be regarded as indecent (L. Kjelldahl, personal communication, 2005).

Some final remarks

With this article, we contribute to the documentation of some particularly interesting and noteworthy historical events in the history of computer graphics in Sweden. For example, today we take powerful graphics hardware systems for granted, and we can find high-precision ink jet plotters in almost every home, but these were new high-tech inventions in the 1970s. Industrial control systems today use large displays with modern GUIs for process control and surveillance, which are clearly reminiscent of early semigraphical displays such as the Semigraph 212 and the Tesselator. Also, the later development of the EyesCream product was no doubt an indicator of things to come, in for example, graphics-based business applications. Now, however, it is extremely difficult for small companies to compete in the computer graphics field because of the broad range of graphics solutions available on PC platforms.

Finally, we note that our presentation does not attempt to be a complete record of early computer graphics in Sweden—we encourage others to complement what we've presented here. An interesting topic for further research, for instance, would be to link these events to the worldwide development of computer graphics documented elsewhere[27–33] and to the ground-breaking video documentary ''The Story of Computer Graphics,'' which premiered at ACM SIGGRAPH in 1999.[34,35]

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