Twenty-four Years of Computer Graphics at NRC

Marceli Wein
Laboratory for Intelligent Systems
National Research Council of Canada
Ottawa, Ontario, Canada K1A 0R6

Abstract

Early activities in computer graphics at the National Research Council of Canada, and a summary of the evolution of computer animation work at NRC in the context of work in other centres of research in computer animation are presented. The article also recalls some events from the early Seminars of the Canadian Man-Computer Society, which became the Graphics Interface Conference, which is the longest running Conference in Computer Graphics. This article concludes with a summary of the contribution of the NRC projects to industrial activities.

Résumé

Cet article rappelle les activités au debut du projet en infographie au conseil de recherches du Canada. Aussi l'article présente un résumé de l'évolution de l'animation par ordinateur au CNRC et aussi il donne une comparaison avec quelques autres centres de recherche en animation. Cet article rappelle aussi quelques points saillants dans le développement des colloques sur la communication entre l'homme et l'ordinateur qui sont devenus la série des conferences Graphics Interface, la plus ancienne conférence en infographie. Cet article conclut avec un sommaire de la contribution à l'industrie par le projet en infographie au CNRC.

Introduction

This article is not a paper, neither in style nor in typically expected content. Instead, it is an informal and a personal fly-through of computer graphics, in particular the activities at NRC, from about 1966 until it became obvious that computer graphics became a large industry and a pervasive topic in many disciplines.

NRC No. 31379

Computer Graphics Project

Early Work

Interactive graphics became established with the publication of Ivan Sutherland's work as well as the recognition of the interesting aspects of the work of Doug Englebart at the Stanford Research Institute (now SRI). I joined NRC just when Ken Pulfer (recently retired as a Vice-President of NRC) started investigating opportunities in the area. Pulfer, Nestor Burtnyk and Grant Bechthold had just completed projects in defence (electronic counter measures).

After visits to SRI and to MIT, we started a serious project in interactive graphics, which involved a transition to the field of computing and digital hardware. The basis of the work was a point-plotting display from Information Displays Inc (IDI). Carl Machover was vice-president of IDI and subsequently became well known consultant. Starting with the point-plotting display we designed and built the display processor, line or vector generator and character generator. The display processor had a conventional instruction set and was competitive with systems that entered the market up to three years later. The display was organized with a centrally located screen and a number of interactive devices on each side (Figure 1). Visible in Figure 1 are the pair of orthogonal thumb wheels on the right and the left-hand keyboard just visible on the other side. The keyboard is shown in detail in Figure 2. Complementing these devices was a home-built mouse, shown in Figure 3, patterned (together with the L.H. keyboard) after the work of Englebart at SRI.

The first demonstration, for an Open House in 1966, was mounted before our computer was delivered. A magnetic tape drive and controller were connected to the display controller and simulation sequences of a moon-shot rocket were played directly from tape to the display. The simulation sequences were computed

Figure 1. The early interactive system at NRC

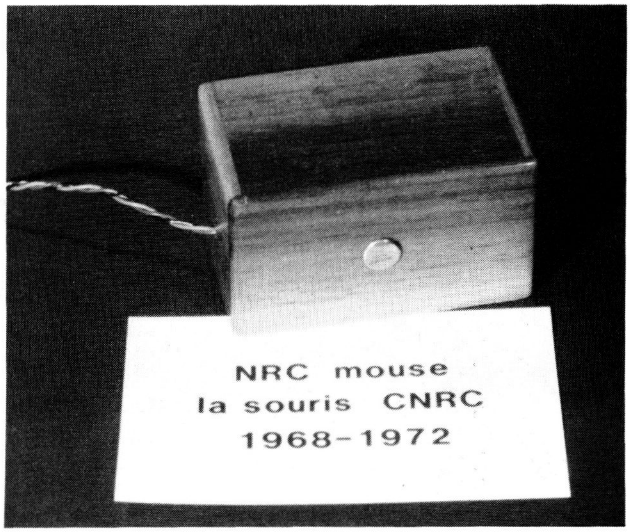

Figure 3. Home-built mouse

Figure 2. Left hand chording keyboard

on an IBM 360/50. Thus the first real use of the display was to show continuous motion, kinematics and dynamics, though not interactive. Most of the early work was based on the interactive display and an SEL 840 24-bit minicomputer (from Systems Engineering Laboratories, later Gould SEL) equipped with 24KB of memory and designed for realtime data acquisition The realtime aspects proved to be extremely valuable.

In the period 1967 to 1968 we started projects in animation and in music, both of which were based on an approach that a highly interactive style that was visual and did not involve keyboard commands would suit the non-technical user. The early work in animation involved an interactive style for constructing geometric objects and for drawing free-hand images, however, the specification of the animation was language based. Although the language was primitive, it had one interesting feature: each statement applied to a specified time interval. Consequently any one frame of the animation sequence was affected by several statements whose range bracketed that frame. A curious consequence was that the order of the statements did not matter. Neither the language nor any subsequent system had an acronym name. We did not appreciate the importance of a software package to have an acronym name and the project team have a T-shirt design.

Experience with the language led us to the conclusion that animation by moving and rotating rigid objects was extremely limiting and basically uninteresting. Also, specification of animation as a set of statements was counter-intuitive, requiring many iterations to achieve some desired affect. We concluded that in general, a language for graphics or for animation was not a fruitful route to explore. However, the language was retained for any special application when it was appropriate.

Conferences

When the project got underway, there was a sense of isolation. While it was known that interest in graphics was growing, there was no forum for the exchange of ideas. There were essentially no publications and no conferences. By then we were familiar with the work at MIT, SRI and Bell (Telephone) Laboratories, (mainly involved in music, speech and visual perception) as well as with the early work of Charles Csuri at Ohio State.

We organized a two-day seminar on Man-Machine Communications that was held at the National Research Council in May 1969. The seminar was not called *The First* because we did not know if there would be successors. There were nearly 100 attendees, of whom at least 30% were artists, designers and broadcasters. The keynote speaker was J.C.R. Licklider from MIT. He was actually more affiliated with the project in timesharing, the growth of which apparently drove interactive graphics from MIT to the University of Utah. Presentations at the Seminar were from Universities across Canada, AECL, Northern Electric Labs (now BNR), Communications Research Centre and NRC.

The CMCCS seminar continued biannually, sponsored by the Division of Electrical Engineering of the National Research Council, until 1979 at which time the Canadian Man-Computer Communications Society (CMCCS) was formed. The conference moved outside Ottawa for the first time in 1977, but returned in 1979. By then the conference was filling an important role in providing a forum in computer graphics and the attendance reached 400 attendees.

Through the seminar we became aware of graphics activities at University of Toronto, Alberta, Saskatchewan, Nova Scotia Tech, Waterloo (Systems Design) and Manitoba. Subsequently the direction at Toronto became focused with the arrival of Ron Baecker in a similar direction to ours towards motion and interactivity. Somewhat later the Computer Graphics Laboratory at the University of Waterloo was formed and grew to having five faculty members.

Another early forum between 1969 and 1971 was formed in United States as a sub-group of the Group of Users of Computer Output Microfilm (UAIDE). That user group adopted the artsy graphics orphans into the program of the annual meetings and in turn we provided striking contrast to the mainstream attendees at these meetings.

In 1974 SIGGRAPH started with a modest conference in Boulder, CO, but grew rapidly. As a consequence, attendance at CMCCS conferences levelled off but the conferences continued to maintain a solid technical program. The Conference that was held in Waterloo in 1981 was the first of the annual conferences. In 1982 the conference was renamed Graphics Interface, which was a more informative name than CMCCS, and, unlike the name of the Society, was gender neutral[1].

Animation

After early attempts at animation through scripting proved unsatisfactory, Nestor Burtnyk heard, at the 1969 UAIDE meeting in Los Angeles, a presentation on the animation process at Disney Studios. Upon return, Burtnyk started experimenting with software tools for inbetweening. This scheme for computer animation was consistent with our tactile approach. We then embarked to create a working system based on key frame animation. The system would emulate conventional cel animation where image components are drawn on celluloid and assembled into sandwich layers to form entire images. Our approach was to use the computer animation system to simulate the artist's drawing table and to mimic the traditional tools for inking, opaquing, inbetweening, etc. This approach is in contrast to that in a modern computer animation system which attempts to give a tool for creating simulations and abstractions of the real world.

The early prototype had three ingredients: a drawing package, an interactive builder of animation sequences, and an animation playback package. The fourth component, the film recording system, followed later. The drawing package was both a tool for geometric drawing, like a rudimentary CAD program, but was mainly for free-hand drawing. The program also supported tools for animation such as creating layers. Initially the drawing device was a home-built mouse (Figure 3), patterned after the original mouse developed at SRI. The mouse-based drawing style required motion from the elbow, not the more common flexing of the wrist. This style suited some artists especially those who had worked with conté or pastels because these require gross motion from the elbow. Because the artist required registration of image components and of successive key images, the package was converted to use a graphics tablet equipped with standard animation registration pins.

The sequence builder permitted assembling sequences of key frames and could be used as a one- or two-step process. The optional second step permitted merging parallel sequences which might have different timing and rhythm. It was easier to prepare individual sequences separately and to merge them before playback.

The playback package was not interactive and presented a sequence at a rate up to the real-rate, as well as it could. While it was playing, the viewer could specify to compute every second or every fourth frame in order to maintain real-rate playback. A second approach used a raster display (which was gaining popularity) to give true real-rate playback at a low resolution.

[1] Several attempts in prior years were made to find an alternative name for the Society that was gender-neutral but they had failed to produce a satisfactory alternative.

Once a prototype system was working, we established contact and collaboration with the National Film Board, specifically the French Animation Section under René Jodoin, who were interested in experimental techniques. Under the NFB collaboration, we started early in 1970 to work with the late Peter Foldes who was a brilliant artist, resident in Paris, but under a contract with NFB. The first experimental film *Metadata*, which is still in the NFB catalogue, was a vehicle for exploring ideas and was done quickly and essentially without a script. All the key images in the film were drawn with the mouse.

The important decision that followed was due to the visionary outlook of René Jodoin who was both an animator and director but acted as the producer for our work. While there had been many demonstrations of feasibility, the next step was make a real and substantive film working from an approved script and an approved budget. The script for the film *Hunger* had been submitted by Peter Foldes to be made with conventional cel animation. The decision was to make it on our system on a schedule that would bring the artist from Paris for three-week intervals, between which we could make major enhancements to the software. The system evolved during the production spanning 1971 and 1972 such that every enhancement was made in response to a specific requirement in the script. Thus long before the current vogue arrived at NRC to steer R/D to be responsive to real needs in the real world , the animation project was driven entirely by the specific requirements arising from the script and therefore by real problems.

After lengthy experiments in the optical department at NFB during 1973, the film was completed late that year. Its main success at the time was as a film with a story. It was also the first significant computer animated film with figure animation. The film won about eight awards including *Prix du jury* at Cannes and a nomination for an Academy Award, both in 1974. In figure animation, there have been essentially three milestones: *Hunger*, *Tony de Peltrie* and *Tin Toy* all with Canadian content. Another project that was produced on the system were all the computer generated sequences for the BBC series *The Ascent of Man* with Jacob Bronowski. The last hope for the producer of the series was NRC. They needed to produce a wide variety of sequences which had to follow a script. The system had to be flexible and general. The NRC system met these criteria and they were able to produce all the required sequences.

Film Recording

The final difficulty we faced was in film recording. Film recording was a relatively new art and colour recording using colour filters was just being introduced. The style that we wanted to achieve was to mimic cel animation where areas of colour are bounded by black lines. This comic book style is known to be forgiving when there are registration errors because they get covered by the black lines. However, recording colour areas bounded by black lines on film requires a subtractive process and the process continues to be difficult even on modern film recorders. Another problem was that at the time, film recording was primarily geared to B/W microfilm recording, so that suitable precision cathode-ray tubes with broadband white phosphor for colour recording were not available.

Consequently, the film *Hunger* and several other short films were recorded on black/white film and the colour was then added in an optical printer. Two passes were recorded as two separate 35-mm sequences. The first one was the line image and the second one was a solid black mask. A composite frame is shown in Figure 4. The two images were combined in an optical printer where the line image was used as a subtractive layer (called bi-pack) to produce black lines.

Ingredients for Success

There were several factors that contributed to the success of the early work in interactive systems at NRC. These were the involvement with animators (and musicians in the interactive music project), the choice of the computer, the user interface and the interaction style.

There were many early examples of application of computer graphics to the original arts and animation which were being done by scientists and engineers. Their amateurism and a lack of artistic quality made it clear that a successful project had to involve artists. Furthermore, the interaction style had to provide a sufficient expressive power and generality such that

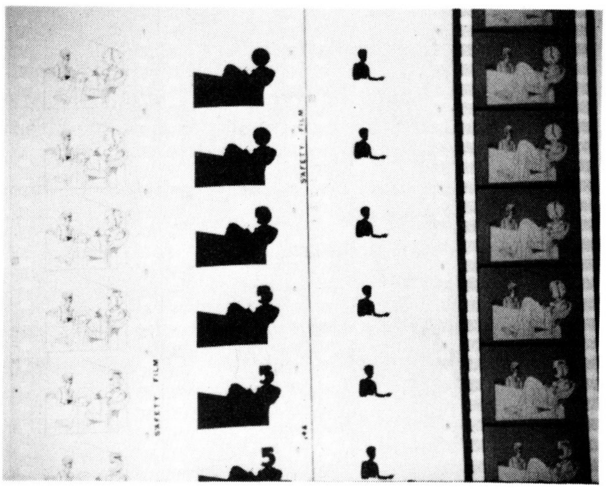

Figure 4. Compositing a frame of animation from a line image and a mask

the result would carry an imprint of the artist and to a much lesser extent that of the computer. It is accepted that a charcoal drawing has a different style from an oil or watercolour painting but foremost there is the style of the artist because the tools give sufficient tactile expressive power. The animation system had to have the expressive power within the limits of the available hardware. Early and intense involvement of the film makers at NFB made that difference in the project.

The second factor was the choice of the computing platform and of the user interface. Project team members were engineers with a background in realtime telemetry and data acquisition. The computer that was chosen was the SEL 24-bit minicomputer intended for realtime applications. It had a minimal command interface and a most primitive file system. In contrast, the PDP series (-1, -7, -9) from Digital Equipment, which were already well-known and which had a strong presence in Canada through applications at AECL, had a well-developed command interface with scripting and option switches on commands. Although we moved later to a PDP-11/45, by getting the the SEL computer, we avoided the strong bias towards text command interfaces that was then emerging and was being followed by almost everyone else.

The access to the system was entirely through the screen and the interactive devices. A user sat down at the display and started working entirely by using the input devices and not the keyboard. The main channel of communication for the single user was through the graphics display. The command executive was a menu-based scheme for access to the file system. The file system that was supplied by the manufacturer was a flat system, basically a depository for objects. The screen-based system we super-imposed on top of the supplied system, created a tree-structured hierarchical file system. Each directory could hold up to 16 items (either objects or pointers to a sub-directory) which was the size of the menu on the screen. The current directory on the screen was always "live" such that additions or deletions were automatically reflected on the screen, i.e. there was no need for an *ls* command.

This screen oriented access scheme was used both at the "system command level" to start an application and from the application to save, delete and retrieve objects.

Interactive Computer Music

The project in interactive computer music was a closely related project which we considered a part of graphics because it shared common goals in the style of interaction and used the same computer system. The music project was primarily the responsibility of Ken Pulfer and Peter Tanner and in 1970-72 created an interactive, visual environment for writing conventional music notation on the screen and for specifying the desired timbres and sound characteristics. Realtime playback was entirely digital, being generated by nested loops written in assembly language and highly optimized to give timing and pitch precision. During playback the display scrolled the music staff to match the playback.

The approach, using all-digital sound generation in software and without any analog hardware, had its limitation but it avoided the nuisance of manual patch cord schemes of interconnection. It was only in early eighties that solid state analog switches eliminated patch cords in music synthesizers.

Bill Buxton was a music student when he started working on our music system. He has often expressed highly complimentary opinions about the system. One factor that encouraged him to enter the field of computer music and computing in general was his belief that our style of interaction was common in most centres of research in computer music. In fact, that style did not become common until about 15 years later.

Industrial Involvement

One of the mandates of NRC has been assistance to industry, stimulation of industrial research and interaction with industry. The computer graphics project offered an opportunity to stimulate activity in the discipline in industry through collaborative projects with partial funding from NRC and through Research Grants. Nestor Burtnyk and I have had the opportunity to be involved in a number of industrial projects.

Our first exposure to the process was a project with Digital Methods Ltd. to rewrite the NRC animation software in FORTRAN and to port it to a PDP-11 computer and install it at the National Film Board. The animation system was originally written in Assembly language for the computer that was about to be scrapped. While the imminent loss was a lesson in portability, there was no regret, because we could not have achieved what we had, if we had written the original system in FORTRAN. The resulting system was installed at NFB in 1976 and it was a useful first step for NFB in starting their computer animation studio, and it was worthwhile for Digital Methods to learn about building a large graphics application.

An interesting collaborative project in mid seventies with Norpak Ltd. was the development of a high performance frame buffer peripheral for a minicomputer. Wayne Davis was a consultant on the project and contributed to the definition of the command set. The frame buffer was a powerful peripheral for its day. It was a 24-bit frame buffer with programmable synchronization and frame formats, including 512 square, 640 by 480, 1280 by 960 pixels. The system had genlock to external synchronization. Local command processing was carried out on a bitslice processor, an architecture that later became fairly common on many systems from many manufacturers. The system had good potential and a number of them were installed but Norpak redirected its efforts to Videotex and away from mainstream graphics.

Another project involving collaboration from the graphics group and partial funding from NRC was the development of the Orcatech 3000 workstation, in particular the 3D geometry processor which used Weitek floating point chips. The 3D system had throughput that was comparable to the early SGI workstations. That project started in 1982 and was at the height of the JAWS era with hundreds of manufacturers making Just Another Workstation, and the hope was that a powerful 3D processor would set that one apart. However, rapid growth and maturing in the industry overtook Orcatech and caused its demise.

Another interesting graphics project in mid-eighties in which I was involved was with Vertigo (now Cubicomp) in Vancouver in the development of their animation system. The system included a powerful modeller, based on the concept of extrusion and a renderer that executed on a multiprocessor under the NRC Harmony operating system. Easy and intuitive schemes for modelling objects were always of high interest and the extrusion approach developed at Vertigo proved to be quite innovative. The project was marred by the tragic loss of Tim Piper who had joined Vertigo from University of Toronto and designed the multiprocessor.

There were other gratifying industrial projects, not necessarily in graphics and for which all I had to do was to be enthusiastic have a little vision and to recommend contribution support. One small contribution was to Alias Research which was crucial because it was right at their beginning, when there were only three people involved. Another one was the development of the original Mitel telephone switch, the SX200, with a solid state analog switcher. I knew very little about telephone switching but reacted to a sense of excitement and innovation. The other project in the same category was the development of the Geac 8000, a specialized minicomputer which is still being used in banking and in many libraries.

An exciting period of industrial involvement was the period of development of Canadarm or the Shuttle Remote Manipulator System (SRMS) and its simulator. We acted in a consulting role to the SRMS simulator project in the area of realtime graphics and user interfaces. As a consequence we built a demonstration system that performed hidden-line removal in a realtime display with modest hardware complexity. The requirements for realtime scene generation were about five years ahead of the availability of reasonably priced surface rendering systems that are common today.

Standards for Computer Graphics

Activities in the Computer Graphics Group were at the time of a rapid growth in the industry and increasing awareness of needs for suitable standards. The emergence of graphics standards, first under ACM/SIGGRAPH and later within the formal standardization bodies, ANSI, CSA, ISO (American National Standards Institute, Canadian Standards Association, International Standards Organization respectively) and others attracted many research people and represented an exciting period in that activity before the process entered its mature phase.

Following early work within professional societies, various national working groups began forming including the formation of the ANSI Technical Committee in 1978 and of the CSA/Standards Council Working Group in 1979. The main activities were in the period 1980–1985 during which Canada participated as a voting member. During that period, the main effort in the Graphical Kernel System GKS and on the Computer Graphics Metafile (CGM) was completed although the formal processing through the ISO machinery took much longer until these standards actually emerged.

The Canadian Working Group had seven truly active members and a larger number of intermittent contributors. The group made significant contributions to these two standards through working papers and drafts of the portions of the standard documents, particularly the CGM document. Other contributions of the group were in mitigating the polarization between the USA Core document and the European GKS document, as well as reconciling the parallel developments of graphics standards and videotex standards.

The pace of the standardization turned out to be too slow. By the time the standards became available, first as documents, then as implementations, they were long overtaken by technology. Both these standards had imaging models appropriate for the calligraphic displays of the Seventies and only token support for the raster displays of the Eighties. Above all, jurisdictional issues in the formal standardization process precluded the development of a consistent and integrated imaging model for graphics and text. The design of such a model must recognize that text is a subset of graphics. However, the dominant model emerged from the older committees that dealt with text and which assumed that graphics was a subset of text and confined to graphics boxes in a document. Integration of a consistent imaging model continues to be a problem in the standards arena, although it has long been solved in the *de facto* commercial standards, PostScript being but one of them.

Conclusion

The projects in interactive music, animation and finally interactive graphics ran their cycles and were terminated for various reasons. In some ways being too much ahead of the available technology in these projects we missed the opportunity to lead to more significant commercial results. The music project was terminated in 1972 when Pulfer started his rise through the management structure. The animation project was terminated in about 1976 because the consensus was that after a convincing demonstration at NRC the NFB was a more appropriate place to carry on that work. Also, the general trend in animation was to exploit high quality rendering of complex surfaces with reflective properties, which required massive computation, were intractable to responsive interaction, yet produced spectacular visual effects but ultimately were dull animated logos.

The graphics project, where graphics was a goal in itself, was terminated in mid-eighties when it was evident that graphics had matured into a major industry and had entered many application areas. At that stage a four-person project in graphics in a government laboratory no longer made sense. On the other hand, the topic of interaction and of user interfaces continues to be an active topic in the context of the current activity in multiprocessor architectures and operating systems.

References

No specific references are included for two reasons. First, this is an informal article rather than a paper. Second, it would be impossible to give a complete set of references. Instead, the reader is referred to the fine ACM/SIGGRAPH bibliography of which both the present and past editors represent a Canadian presence.