New Media, Games & Animation Activities of the Computer Graphics Laboratory

Bill Cowan

1 Overview

The Computer Graphics Laboratory (CGL) came into existence in about 1980. Two professors originally hired as theorists, Kellogg Booth and John Beatty, became interested in computer animation. They began collaborating with Marceli Wein of the National Research Council of Canada (NRCC), a computer scientist who, a few years earlier, had been central to a team that partnered with the National Film Board in making the short computer-animated film, *Hunger*, which was nominated for an Academy Award. When pressed to provide a firm date for the beginning of CGL Kelly and John mention writing the Strategic Grant application that provided the first dedicated graphics hardware at UW, which occurred in 1979.

Computer graphics was at that time, a young subject; within a few years John and Kelly made CGL prominent in the Canadian and indeed the North American computer graphics community, organizing Graphics Interface in 1982 and SIGGRAPH in 1983. In the early 1980s Richard Bartels and Bill Cowan joined CGL, taking it in two new directions. Richard worked with John developing the computational mathematics of spline-defined curves and surfaces. Bill worked with Kelly investigating the link between the computer-generated image and its human viewer. CGL was at that time, the late 80s and early 90s, a leader in the new surface description technologies that are now an essential part of computer-aided design and modelling for computer animation. It was also a leader in controlling colour in computer imagery, which is necessary to support artistic creation using computer tools, and in empirical measurement of the response of viewers to interactive graphics, which is at the heart of game design and creation. These strengths continue to the present.

Stephen Mann joined CGL in the mid 1990s, strengthening our effort in curve and surface modelling. He and Richard extended that work to investigate user interaction in the modelling process. At the same time Michael McCool joined CGL and began a new research theme that has become an intrinsic part of every game and computer animation, using the graphics processing unit (GPU) to do as much as possible of the essential rendering process. The result is as much as a hundred times speed-up in graphics for games, without which the very realistic computer games in existence today would be impossible.

At about this time Cowan's research in the perception of computer-generated imagery began showing that the route to more effective images lies as much in understanding the practice of artists as in improving the speed and fidelity to optical physics of rendering computation. From this work he presented an invited talk, 'Rendering with Limited Means', that drew analogies between the constraints faced by an a painter and the constraints faced by algorithmic rendering, showing methods by which less fidelity could produce more realism. This talk has subsequently been described as 'seminal' in the development of the then-embryonic field of non-photorealistic rendering (NPR). Shortly afterwards Craig Kaplan joined CGL, developing a new research theme in NPR, with an emphasis on the two-dimensional patterns that games map so extensively onto most surfaces, which provides a great increase in 'realism' with low computation cost.

Despite the importance of this research it is dwarfed by twenty years of educating undergraduate and graduate students. Computer graphics is a part of the Canadian software industry that punches far above its weight on the world scene. This is possible only because two computer graphics groups, CGL and the Dynamic Graphics Project at the University of Toronto, began graduating large numbers of well-trained bachelors and masters graduates. These students staffed the many companies that have grown up in Canada since the early 1980s: programming modelling and animation systems (Alias-Wavefront, Soft Image, Side Effects),

developing computer games (Electronic Arts, Radical Entertainment, ...) and computer animation (Core Digital, ..., ...). Many of these programmers and designers learned their craft in 'Introduction to Computer Graphics', Waterloo's flagship course in computer graphics. Maintaining and improving the quality of this course, which has been much imitated at other universities, has been an important achievement of CGL.

The remainder of this document fills in much concrete detail that is missing from this sketch, focussing on animation, new media and games.

2 Animation

CGL has, from its beginning, performed research that contributed to computer animation: for example, spline curve modelling algorithms that are used to create and edit motion for in-betweening and colour calibration models that are used in transferring content from video to film and in projector calibration. Many students in the undergraduate graphics course do animation for their projects, and gain a practical understanding of animation software that they then take into the workplace.

2.1 Complete

Academy Awards. Professors and graduates of CGL have received two Academy Awards for Technical Achievement, which are given for technical advances that qualitatively change how movies are made. All these awards are in the areas of computer animation or digital special effects.

- 1996, Marceli Wein, pioneering work in the development of software techniques for Computer Assisted Key Framing for Character Animation.
- 1997, Paul Breslin, co-development of the procedural modelling and animation components of the Prisms software package.

CGL graduates have also received two Scientific and Engineering Awards from the Motion Picture Academy.

- 1997, Rob Krieger, co-development of the geometric modelling component of the Alias PowerAnimator system.
- 2002, Paul Breslin, co-development of the procedural modelling and animation components of the Prisms software package.

Note that there are actually two different types of Academy Award for contributing science and technology that qualitatively improves the technical side of making motion pictures. Awards for Technical Achievement are lower level awards. Scientific and Engineering Awards are the higher level awards, and are given for more sustained contributions.

Movie Credits. Many graduates of CGL have made careers in digital animation. The more successful ones have obtained credits on major Hollywood films. Here is a, certainly incomplete, list.

- Barry Fowler: Shrek the Third, Flushed Away, Over the Hedge, Madagascar, Shrek 2, Shrek, Antz.
- Josée Lajoie: WALL•E, Ratatouille, Cars.
- Shawn Neely: WALL•E, Ratatouille, Cars, Shrek, The Road to El Dorado, Forces of Nature, Antz, Double Dragon.
- Selina Siu: The Wild.
- Rafal Jaroszkiewicz: The Wild.

CGL animations.

- Only You Can Prevent Flying Logos
- Geromino
- Centipede

FINE 328.

2.2 Ongoing

Slow animation. The perception of motion can be mediated in two ways: by motion sensitive cells firing in the visual cortex, and by percepts in the present that differ from memories of the past. The artistic content related to change in animated art is primarily perceived by motion sensitive cells. Fine Arts professor Doug Kirton and Bill Cowan are working together in developing slow animation, in which change happens so slowly that its perception is mediated only by memory. The goal is to give artists the capability of providing the viewer with the experience of motion without motion. The idea is to confound the distinction between contemplative viewing and focussed viewing, which is a major theme in modern art, informing works as different as Andy Warhol's *Empire*, and Robert Smithson's *Spiral Jetty.*

The principal result of this work is the M.Math. thesis research of Josée Lajoie, who created a slow animation of an orrery, complete with Tintin's space ship.

Student Animation.

3 Games

Games are the most prominent member of a group of applications that are best described as interactive animation: an animation engine provides a view[1] into a simulated world while viewer input changes the state of the simulated world. This category includes virtual environments, augmented reality, animated visualization and many other applications in addition to games. When thinking about research we group them together because they are all based on the same technology: technical improvements to one member of the group normally spread quickly to the other members.

The main technical advance demanded by interactive animation is real-time. Humans are unavoidably real-time systems. There is some slack: humans can slow their responses when the system is slow, and with learning, they can speed their responses when the system is fast. But there are limits. Humans provide responses conditioned on visual input with latencies no less than a few hundred milliseconds; humans required to slow their responses much beyond three to five seconds. This range is narrow, and somewhere in the middle of it is a sweet spot that varies from application to application, and that changes as the user increases his or her skills.

That being said, the main challenges in game technology lie with the artists and game designers. The challenges in computer science that are unique to game design are truly real-time interfaces and tunable software, as described above.

3.1 Complete

Tux racer.

3.2 Ongoing

Game tuning. A game stands or falls on playability. In an age where high levels of realism are possible it is revealing to notice the ongoing survival of simple games like Pong and Asteroids and simple gaming platforms like the Wii or the Nintendo DS. The answer is that a simple game, well-tuned to provide the user with scenarios that are feasible, but difficult enough that the user gets a sense of achievement, can be as satisfying as one that is far more complex. The property is called 'playability' and is recognized in the game industry as the make it or break it factor in the market success or failure of games.

There is at present no complete model of playability; such a model is most likely to arise in research on applied perception (§5.3). Yet, the many students who aspire to careers in game programming need an exposure to playability. They are given this exposure in a module of a third year course developed in CGL, CS349, where they learn how to make tunable software, are given an introduction to the basic psychophsics than underlies playability, and are required to create and tune a real-time game.

Liquimedia. Rob Kroeger's Ph.D. thesis (2004) is a response to the need for real-time processes like video or audio replay or voice-over-IP to co-exist with interactive control. It did so by creating a cyclic executive capable of handling badly behaved foreign executables without mishap. This behaviour is possible because it exploits differences in the natural time scale of the user and of the micro-slices (the order of a few microseconds) to do statistical admission control. This work, which we are continuing to follow up, is essential infrastructure for games and many other types of new media.

Computer-designed architecture.

4 New Media

New media is a slippery term. Undoubtedly the underlying concept is the development of new ways to create and integrate different methods for delivering content to one or more modalities of human perception, with the strong implication that artists and designers can and do use the technology to express themselves in novel ways.

That being said, the effect of new media research is often the democratization of artistic creation.

1. The word 'view' is here used in a generalized sense, including other modalities such as audition, touch and proprioception.

YouTube, for example, creates something new in the media space merely by providing a distribution mechanism that makes artistic investment worthwhile by assuring the creator that his or her work will be placed before the eyeballs of intended viewers. In a very different way so too does Second Life. In CGL we have believed that democratization is equal in importance to other aspects of novelty, and our research has been directed accordingly, partly toward the requirements of the artistic elite, partly toward those whose artistic creativity has, until recently, had no outlet.

4.1 Complete

Grant Selection Panels. Bill Cowan was on the grant selection panel for Canada Council/NSERC New Media grants, for its first two years, during which the panel created a practical definition of the interaction between technology and artist in new media.

A music composition assistant (2006). M.Math. student Edwin Vane created a system capable of building soundtracks for videos based on musical input that is well within the capability of an ordinary user. This system is unique in splitting creative control into two parts. At the beginning the user splits the soundtrack into cues and provides three to ten note motifs assigned to the cues. The system then provides a variety of possible soundtracks for each cue from which the user selects. The significance of the system is the democratization of soundtrack composition. Ordinary users can create soundtracks for their YouTube videos, having complete creative control while needing no more than the musical knowledge that is taught in primary school.

Chris O'Sullivan. Virtual environments

Margaret Dulat. The force buffer

4.2 Ongoing

Assistance for the Blind. Current Ph.D. student Martin Talbot came to our graduate program following fifteen years as a musician, composer and sound engineer. Supervised by Bill Cowan he is, for his Ph.D. research, creating a media space for the blind. The goal is to create a tactile and audio environment that simultaneously provides the aesthetic pleasure of musical sound and the quantative environmental information that a blind person needs when navigating in the world. His approach to this work uses the methods of Applied Perception (§5.3) of which Cowan is an acknowledged leader. That is, Talbot subjects his designs to experimental testing, building as he goes along a body of knowedge that has broad relenace and utility, and which will be useful for the construction of more complex media spaces for all eyes-free environments, such as driving.

Computer-designed architecture.

Calm technology. It has long been observed that only a very small part of visual perception (less than 1%) is processed to a level at which it can accept attention. The remainder is used to support automatic processes, activites like maintaining balance and hand-eye coordination. Three remarks about automatic processes illustrate their importance.

- Attention is a limiting resource. The main purpose of learning is to automate attended activities, to free up attention for other uses. People we consider to be highly skilled are also highly automated.
- Technology-oriented media research is focussed on attended activities. The most productive current direction for media research is in the area of unattended processes.
- Information is transferred to long-term memory as a result of unattended processing, and is therefore available at later times to attended cognition.

These observations are the basis of a distinctive approach we are taking to calm technology, which is the science of artifacts that are pleasant additions to a user's media environment, and which provide valuable contextual information through unattended perception. M.Math. student Vladimir Levin, who graduated in October 2008, created calm artifacts that provide useful information to the user's long-term memory while requiring no attention. Supervised by Bill Cowan, he proved the success of his design experimentally using the techniques of Applied Perception (§5.3).

5 Foundation Activities

The research in CGL that provides new technology for animation, new media and games is actually an

offshoot of several research themes pursued by CGL faculty members. The following sections briefly describe the main themes, the important past results and current goals.

In considering this record, however, it is important to remember that, as much as possible, CGL faculty try to support whatever research the students wants to do, without shoe-horning it into major projects architected by the supervisor. The variety of thesis titles, which are available on the CGL home pages (http://www.cgl.uwaterloo.ca/thesis.html), attests to our willness to support an eclectic mix of research.

5.1 Curve and surface modelling

5.2 Colour

5.3 Applied Perception

5.4 Real-time Graphics

5.5 Non-photorealistic Rendering

6 'Typical' Graduates

Christin Barghiel. Currently director of Product Development, Side Effects Software.

Paul Breslin. Long time employee of Side Effacts Software, Inc. Winner of two Academy Awards for science and Technology. Currently Senior Software Architect at AutoDesk.

Lijiang Fang. Principal Development Manager at Microsoft China.

Josée Lajoie. Now a technical director at Pixar after completing an MFA at CalArts.

Joanne McKinley. One of the principals at ReqWireless, Inc., which was absorbed by Google. Currently a Senior Software Engineer at Google.

Blair McIntyre. Computer Science Professor at Georgia Institute of Technology.

Milan Srekovic. Software Development Manager at Autodesk after many years as Engineering Director of Alias and Alias/Wavefront.

Colin Ware. Computer Science Professor at University of New Hampshire, seminal figure in information visualization and applied perception.

7 Spin-off Companies

Preston Gurd. Archelon Inc., purpose was to commercialize a compiler for graphics hardware, which he developed in CGL.

Jeromy Carrière. Quack.com, (http://en.wikipedia.org/wiki/Jeromy_Carriere).

Jay Steele. Plazmic Inc., acquired by RIM in 2001. Now Viigo Inc., founded in 2004.

Robert Kroeger. Liquimedia Inc., purpose was to commercialize Ph.D. thesis research.

Jasmin Patry, Mark Riddell. Sunspire Studios, purpose was to commercialize a game originally created as a project in the undergraduate course, Introduction to Computer Graphics.

Michael McCool. Rapid Mind Inc.

8 Statistics

8.1 Historical

Age of CGL. circa 25 years.

Average number of faculty. circa 3 faculty.

Number of graduates. At least 131: 117 M.Math.; 14 Ph.D.

Number of papers published.

Employment of graduates. Roughly three-quarters in industry: one-quarter in Ontario, one-quarter in Canada ex Ontario, one quarter outside Canada. One quarter in government and academia.

8.2 Current

Number of faculty. Four, one on unpaid leave.

Number of students. Seventeen: eleven Ph.D., six M.Math.