Welcome to the 11-th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision 2003!

Jack E Bresenham
Winthrop University
Rock Hill
South Carolina 29733, USA
j.bresenham@computer.org

INTRODUCTION

Having had my 65-th birthday this past October 2002 and planning to retire this coming May 2003 after 27 years in development groups at IBM followed by 16 years teaching computer science at Winthrop University, I hope you will permit me briefly to reflect a bit on the past. You'll spend the week hearing about leading edge research, development, and implementations in computer graphics. For a few minutes this morning, I propose to look back about forty years in the past.

I'm amazed at how far and how fast has been the spectacular progress in computer graphics. Many, many people have driven the rapid advancement of this mix of art and science. I feel very fortunate to have been a part of the early work. In addition to a good deal of professional satisfaction, I've also gotten to meet many interesting people along the way and hope I'll have a future opportunity to meet some of you personally as well.

Learning how things are done and realizing that nice descriptions in books or journals seldom describe an actual development process that is more chaotic with mistakes made before the final result comes together is important, I think. Some forty years ago I happened to be in the right place at the right time and well prepared with analytical tools provided by my geometry teacher at Clovis High School, the University of New Mexico electrical engineering faculty, and the Stanford University industrial engineering faculty.

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In early 1962 I transferred from Quality Engineering in manufacturing at IBM San Jose to a programming job in Dr. Gene Lindstrom's newly established Computation Lab in development. Engineering manager Kemp Allen had just completed connecting, via the 1407 typewriter console, a Calcomp incremental plotter to the IBM 1401 computer. As the new person, I was given the task by Dr. Al Mitchell and David Clark to write a program to drive the plotter so engineers in the development lab could plot data, as well as view numerical listings, of their FORTRAN program output.

After a first false start, my second approach worked for lines. As best I can recall, my initial objective function must have been to minimize distance from each selected lattice point to the line's true end point. Anyway, the lines did not look good. In computer graphics, aesthetics counts!

My second attempt was to use an objective function of minimizing the normal (perpendicular) distance from the true line to the selected lattice point choices at each step. I saw the problem as the inverse of what Dr. Jerry Lieberman at Stanford taught me in his engineering statistics course when he showed how to fit a line to scattered data points by minimizing the squared distance error sum. That worked and, surprisingly, is still used today in software and hardware implementations to draw incremental lines on raster devices. My IBM San Jose technical report for line drawing is TR 02.266. In an OEM agreement, the Calcomp plotter later was marketed as an IBM 1627 plotter attachment for the IBM 1620 computer.

I submitted my line drawing algorithm to the ACM national conference in Denver. It was accepted and on Friday 30 August 1963 I presented the paper in session 14C: Simulation and Graphical Output. Also presenting in the same session was Dr. E. E. Zajac from Bell Telephone Laboratories: '*Computer-*

Made Perspective Movies as a Scientific and Communication Tool'. Dr. Zajac described using a domino-shaped (wire-frame) box to represent a satellite and a sphere with circles of latitude and longitude to represent the earth to make a perspective movie studying angular motions of a satellite. The cost was about four to six minutes of IBM 7090 time for one minute of movie on a Stromberg-Carlson high-speed microfilm printer. Who would have thought such initiatives would lead to today's Star Wars and Spiderman movie special effects?

The 1963 ACM national conference was the only one for which no proceedings were produced. At the conclusion of my talk, an editor from the IBM Systems Journal asked to publish the paper I'd just presented. Of course I quickly agreed and it was printed in 1965 as '*Algorithm for computer control of a digital plotter*', volume 4, no. 1, pp. 25-30. Thirty three years later, in 1998, ACM SIGGRAPH reprinted the paper in its publication '*Seminal Graphics: Pioneering Efforts That Shaped The Field*' edited by Dr. Rosalee Wolfe (ISBN 1-58113-052-X, ACM Order Number: 435985, pp. 1-6).

Kemp later asked if I could do circles with as fast a drawing speed so I looked into incremental circles beginning in late Summer or early Fall of 1962. I'd gone to work at IBM in June 1960 when I finished my MS in Industrial Engineering (data processing & statistics) at Stanford. In Summer of 1962 I learned my application to return to school to finish a PhD under IBM's 'resident graduate' program was approved and I could return to Stanford in Fall quarter 1962. It was an unbelievable award; IBM paid each recipient full salary plus university tuition at any approved school in the world. Eugene Grant had been my MS advisor at Stanford 1959-1960; Jerry Lieberman became my PhD advisor upon my return 1962-1964.

Together with my classes, for recreation or as a hobby, I worked out an incremental algorithm to draw circles. The key insight was to observe one could first reduce a choice among three possible lattice points within a circle quadrant by a quick sign test then use a second sign test to pick the better of the two next points or the 'closest' one of eight incremental plotters steps. The decision variables then could be updated by a simple addition or subtraction. The objective function measure was to minimize, at each step, the difference between the square of the 'true' radius and the squares of the three candidate 'closest integer point' radii.

The nice thing about dealing with discrete situations is that one easily can enumerate all possible outcomes and verify an algorithm works. Brute force can solve the original challenge then, as understanding evolves, one can produce a more subtle, better efficiency solution with insight.

During late 1963 I began the circle detailed documentation Dr. Lindstrom required with all programs. As with the line algorithm, I saw improvements as the result of describing how the algorithm worked and went through several revisions. TR 02.286 dated 27 January 1964 from IBM's San Jose lab is the IBM formal technical report originally describing my circle algorithm.

The computation lab used both the line and circle algorithms and I gave copies to Jim Newland and, later, Calvin Hefte of Calcomp. I also put a copy in the software library at Stanford's Polya Hall. Software in those days was 'free'; companies typically gave copies of different routines to one another. Much later I saw how to reduce the pair of tests to a single test employing only two possible steps within an octant; that became the basis for USA patent 4371933 issued February 1983 and the paper in the 1985 NATO conference at Ilkley, England ('*Fundamental Algorithms for Computer Graphics*', edited by Dr. R. A. Earnshaw, published by Springer-Verlag, ISBN 0-347-54397-X, pp. 197-217).

The IBM Systems Journal was going to publish the circle algorithm and sent it around to a bevy of reviewers within IBM for refereeing in late 1964 or early 1965. One reader correctly saw I claimed an incorrect objective function as I stated I was choosing the minimum radius difference rather than the minimum squared radius difference at each incremental step. By then I had finished my PhD at Stanford in August 1964 and was back at work in the San Jose development lab where we all had been drafted into the IBM S/360 systems programming work so well described in Dr. Fred Brooks memorable book '*The Mythical Man Month*'. It was a hectic couple of years. I was in my first IBM management job managing five projects (1)TOS RPG compiler, (2) DOS RPG compiler, (3) OS/360 RPG compiler, (4) a 1401 to S/360 RPG translator, and (5) a tape overlap emulator program. I was a single parent with my daughter Janet starting elementary school, so active participation in computer graphics took a back seat owing to lack of time.

In 1973 or so I happened to read Dr. Pitteway's November 1967 article in the UK BCS publication '*The Computer Journal*' and realized there might still be a general interest in my circle algorithm. I'd worked out what became the appendix of the February 1977 *ACM Communications* article to conclusively demonstrate that, for an integer radius, the algorithm minimized the difference between the true radius and the candidate radii as well as the

difference between the square of the true radius and, respectively, the squares of candidate radii.

When I resubmitted the article to IBM Systems Journal, after nearly a decade lapse, they rejected it telling me their editorial emphasis had changed; such algorithms no longer were of interest. I then sent it to ACM Communications in June 1974; after two separate review rounds and two different editors-in-chief, it was revised to ACM's satisfaction in September 1975 and finally published in February 1977 as '*A linear algorithm for digital display of circular arcs*', ACM Communications, volume 20, no. 2, pp. 100-106.

Publications can take a long, long time in various 'waiting' queues! Documenting one's work tends to reveal simplifications; never shirk documentation in programming. Pick error criteria or objective functions carefully and be sure you're doing what you claim. The refereeing process is very helpful. Getting sidetracked working on more pressing matters often happens. If you enjoy something, though, keep it in the back of your mind and don't discard or totally walk away from it.

Should anyone want to see the IBM 1401 code I used to drive the Calcomp plotter (RPQ#W01372), Van Snyder has placed a copy on his Internet site together with improvements he made. See:

http://math.jpl.nasa.gov/~vsnyder/1401/progs/bresenham/

The site uses nomenclature of IBM 1447; I believe IBM 1627 is more accurate but that is a minor matter. As a variable length instruction computer, the IBM 1401 had some very, very cryptic code written for it. One frequently used the fact register content for operand address fields could be omitted in an instruction when one knew the residual address left when the preceding instruction finished to use only an op code with an implicit address. Before some modern software engineer raises a fuss, stop to remember an IBM 1401 came with 1.4Kbytes of storage and offered an absolute maximum of only 16KB. That is one thousand four hundred bytes and sixteen thousand bytes, not megabytes.

Hardware multiplication and division were extra cost features on an IBM 1401 and very slow. Using only addition/subtraction was essential if one wished to operate the plotter at anything close to its rated speed. Another extra cost feature was printer overlap; it was worth the money as it permitted one to start the IBM 1403 chain printer, then plot concurrently while the printer was busy. I suppose it could be called a poor man's hardware parallel processing feature in today's nomenclature. Plotting thus incurred minimal extra execution time cost; lab engineers though were charged just as though it was a serial, rather than overlapped, process is my recollection.

If you collect trivia, it might be of interest to close with a few bits of computer graphics trivia. Alvy Ray Smith and I both graduated from high school in Clovis, New Mexico. We did not know each other then as he is about six years younger than I and went to school with my younger brother Dick. Alvy and I met years later at a SIGGRAPH conference after our mothers, who were good friends, each mentioned her son worked in computer graphics while visiting with each other in the 1980s. I first met Jim Clark at that NATO conference in Ilkley; he grew up in Plainview, Texas, which is a small town near Clovis. Sometimes it can be a pretty small world!

In conclusion, let me mention a favorite paper of mine. It illustrates, at least to me, that, with patient perseverance, improvements typically can be made to most algorithms or their variants. Ellipses are a shape often done with degenerate instances unaccounted for; that is, they fail in certain instances. Comprehensive testing and a thorough understanding of an algorithm's minutia is always essential. M. Douglas McIlroy in his Bell-Labs technical report: CSTR#155<http://cm.bell-labs.com/cm/cs/cstr/155.ps.gz>, '*There Is No Royal Road to Programs: a Trilogy on Raster Ellipses and Programming Methodology*' (Bell Labs, March 1990, also see the Internet site: **cm.bell-labs.com/cm/cs/cstr.html**) is good reading to encourage anyone not to be discouraged by earlier problem solving attempts that may have been less than successful; keep trying and likely it will ultimately be successful. It also reminds me how easy it is to overlook special instances that can cause an algorithm to fail unexpectedly. McIlroy's *No Royal Road* and Brooks' *Mythical Man Month* each teach useful lessons to all of us involved with computing!

What does the future hold? The past four decades passed quickly with significant advances in computer graphics I'd not always expected so I'll be cautious. Moore's Law assures continued function & quality advances. Entertainment graphics likely will drive R&D. I see intellectual property considerations together with new business models for digital multi media distribution as the most significant matters for the first decade of this new century.

Have a great conference! Remember, people are more important than technology so get to know your fellow delegates as well as soaking up technical innovation. Take advantage of social and cultural opportunities here as well as workshops and paper presentations. Get the most from this conference Vaclav & Dirk have organized and look forward to returning to the 12-th annual conference next year.