Dalhousie Distributed Research Institute and Virtual Environment

Advanced Collaborative Environments

Jonathan Borwein, FRSC www.cs.dal.ca/~jborwein

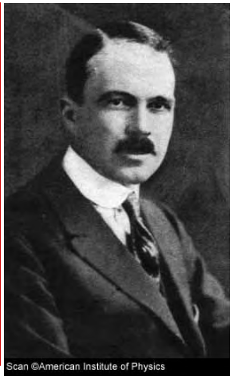
Canada Research Chair in Collaborative Technology

Background: Optimization, Analysis, Number Theory, Computation, Math Phil

"I feel so strongly about the wrongness of reading a lecture that my language may seem immoderate .... The spoken word and the written word are quite different arts .... I feel that to collect an audience and then read one's material is like inviting a friend to go for a walk and asking him not to mind if you go alongside him in your car."

Sir Lawrence Bragg

What would he say about .ppt?



DALHOUSIE UNIVERSITY *Inspiring Minds*

Atlantic Computational Excellence Network

ACEnet

Science Directorate **Board Chair** **Director AARMS**

Revised 27/06/06

Advanced Collaborative Environments

ABSTRACT. Current and expected advances in computation and storage, collaborative environments and visualization make it possible to interact at a distance in many varied and flexible ways.

I'll illustrate some present and emerging opportunities to share research and data, seminars, classes, planning meetings and much else fully even at a distance

URLS. **http://projects.cs.dal.ca/ddrive** **http://users.cs.dal.ca/~jborwein**

http://www.experimentalmath.info **http://www.mathresources.com**

Drive

Challenges of MKM (Math Knowledge Management)

- integration of tools, inter-operability
- e.g., workable mathematical OCR
- intelligent-agents, automated use
- many IP/copyright and sociological issues
- metadata, standards and on

www.mkm-ig.org

MKM
mathematical
knowledge
management
2005

Outline of ACE Talk

A. Communication, Collaboration and Computation.

B1. Visual Data Mining in Mathematics (old and new).

B2. Integer Relation Methods.

B3. Inverse Symbolic Computation.

The talk ends when I do

Much is still driven by particle physics, Moore's Law and (soon) biology **balanced by** `commoditization':

- **AccessGrid**
- **User controlled light paths**
- **Atlas** (LHC hunt for the Higgs Boson)
  - TRIUMF using 1000 cpu, 1Peta-byte
- **Genomics and proteomics**
  - SARS decoded at Michael Smith Genome Centre

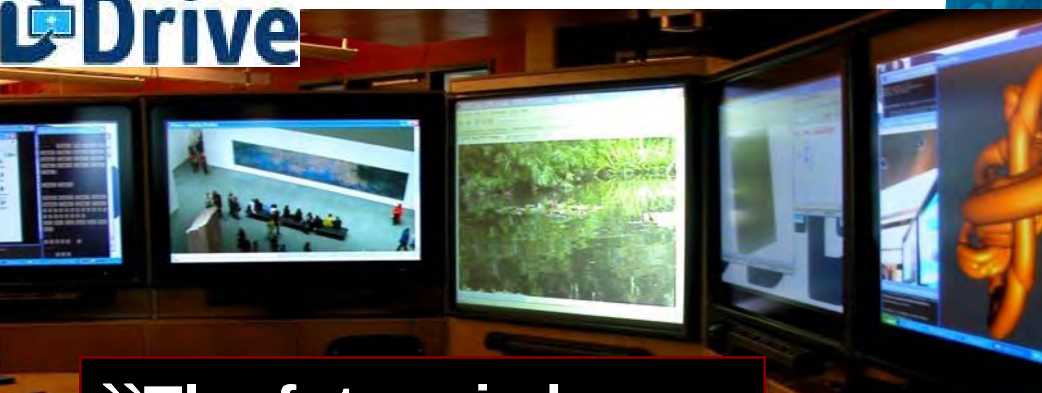
but **WalMart** already stores twice the public internet

WestGrid
www.westgrid.ca

How-To Training Sessions

Brought to you using Access Grid technology

For more information contact Jana at 210-5489 or jana@netera.ca



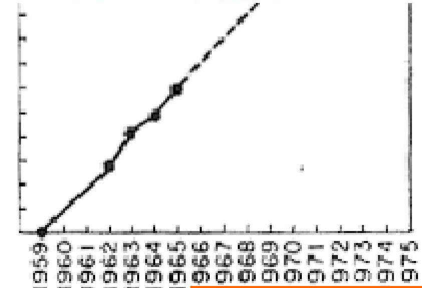
D-Drive

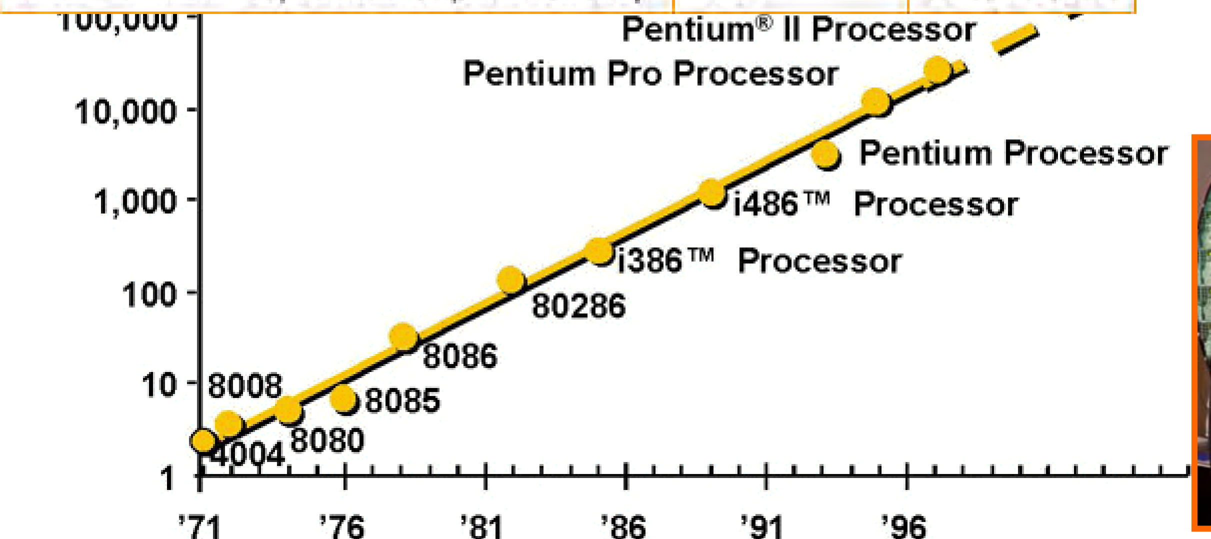
``The future is here… (William Gibson) … just not uniformly''

Remote Visualization via **Access Grid**

- The touch sensitive interactive **D-DRIVE**
- Immersion & **Haptics**
- and the 3D **GeoWall**

Microprocessor	Year of Introduction	Transistors
4004	1971	2,300
8008	1972	2,500
8080	1974	4,500
8086	1978	29,000
Intel286	1982	134,000
Intel386™ processor	1985	275,000
Intel486™ processor	1989	1,200,000
Intel® Pentium® processor	1993	3,100,000
Intel® Pentium® II processor	1997	7,500,000
Intel® Pentium® III processor	1999	9,500,000
Intel® Pentium® 4 processor	2000	42,000,000
Intel® Itanium® processor	2001	25,000,000
Intel® Itanium® 2 processor	2003	220,000,000
Intel® Itanium® 2 processor (9MB cache)	2004	592,000,000





Moore's Law in 1965 and 2005


This picture is worth 100,000 ENIACs
The number of ENIACS needed to store the 20Mb TIF file Smithsonian sold me
The past

Dalhousie Distributed Research Institute and Virtual Environment

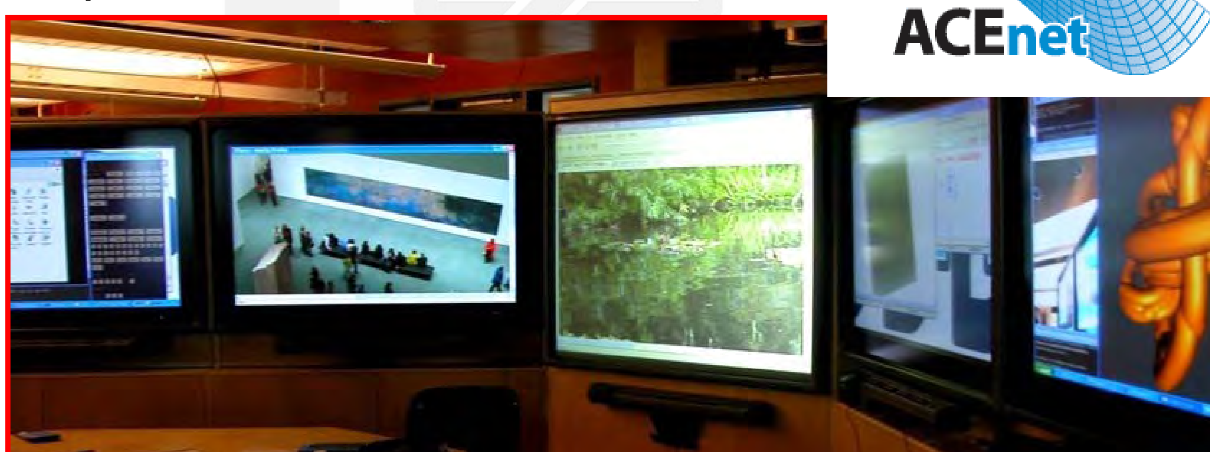
East meets West: Collaboration goes National

Welcome to D-DRIVE whose mandate is to study and develop resources specific to ('dis-located') **distributed research and interaction** in the sciences with first client groups being the following communities

Atlantic Computational Excellence Network

ACEnet

- High Performance Computing
- Mathematical and Computational Science Research
- Science Outreach
  - ► Research
  - ► Education
  - ► Media



D-DRIVE Jon Borwein P. Borwein (SFU) D. Bailey (Lawrence Berkeley) R. Crandall (Reed and Apple) and many others

Staff David Langstroth (Manager) Scott Wilson (Systems) Nolan Zhang (SysOp) Peter Dobscanyi (HPC)

Students Macklem (Parallel Optimization) Wiersma (Analysis/NIST) Hamilton (Inequalities and Computer Algebra) Ye (Quadrature) Paek (Federated search), Oram (Haptics), et al

AIM ('5S' <u>Secure, Stable, Satisfying</u>) Presence at a Distance

Based on <u>scalable</u>

- Topographic
- Dynamic
- Autonomous

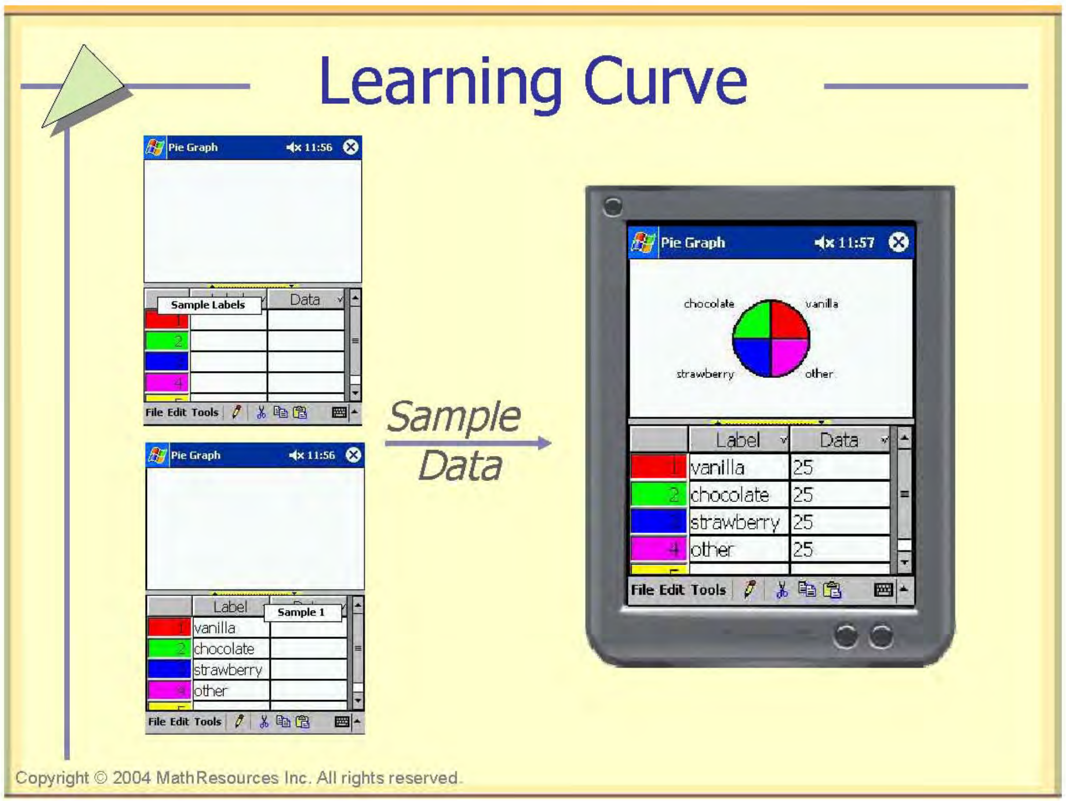
<u>sustainable</u> tools

1996 NSERC Spinoff (15FTE)

www.mathresources.com

Content Provider: putting math and science on handhelds, laptops, web, in classrooms

(LORs and authoring tools) …



D4 Wednesday, December 15, 2004 BUSINESS

Try your hand at new math

Firm develops software to help guide kids through maze of numbers

By GREG MacVICAR

Ron Fitzgerald says math is a language — and most students are illiterate.

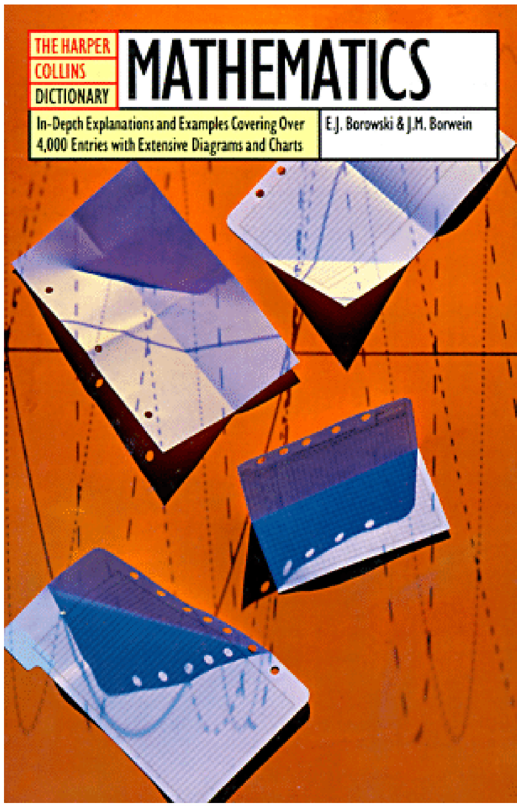
The president of Halifax software company MathResources Inc. wants to change that. That's why Mr. Fitzgerald and his wife quit their jobs as book editors in Toronto in 1994.

Ten years later, he says his company is ready to replace graphing calculators with graphing software for handheld computers.

Ronald Fitzgerald, president of MathResources Inc., holds a hand-held computer capable of running the company's mathematics programs.

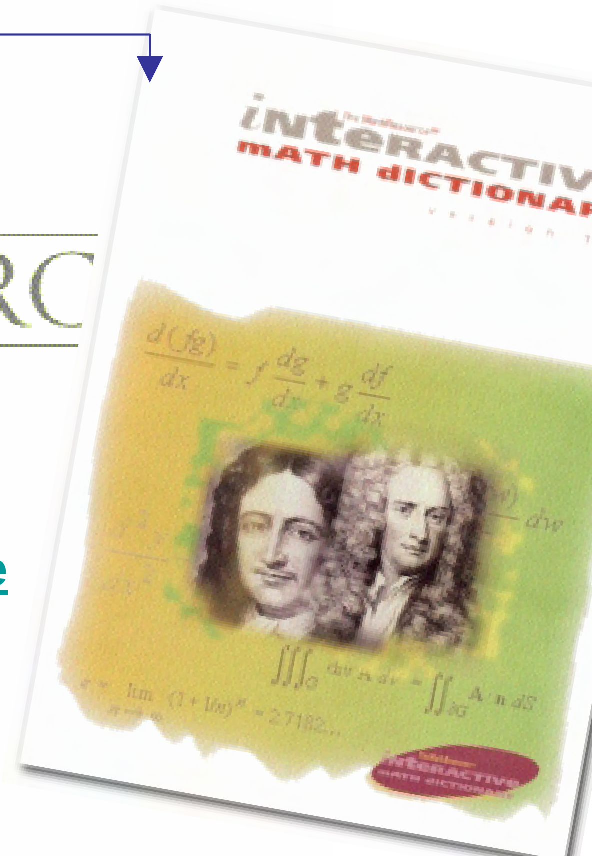
Why show MRI's 1st Product? (1996)

✓ often 10-year lag from R&D to product. Unlike books even 'proof-of-concept' R&D is too expensive for Univ's. As is maintenance.



Maplesoft

- ►Built on **Harper Collins college dictionary** - an IP adventure!
- ► **Maple** inside the MathResource
- ► **Database** now in **Maple 9.5/10**
- ►**CONVERGENCE?**



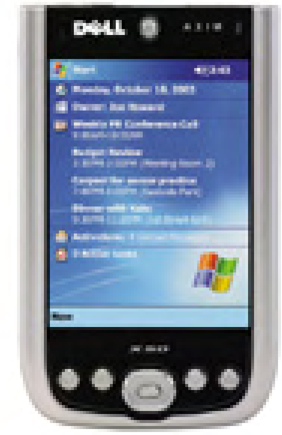
FOR USERS OF Windows Mobile™ PDAs & Smartphones

www.PocketPCmag.com

POCKET PC MAGAZINE

Bringing Math Concepts to Life at Robert Morris College

2005



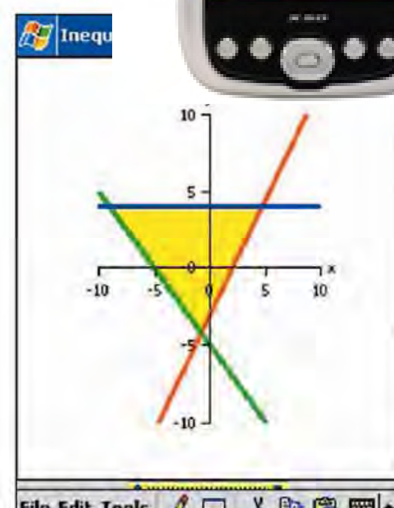
by Dawn Henwood

It's just another Wednesday morning in a small applied math class in Chicago's Robert Morris College, but instructor Ed Clark is conscious that he's at the epicenter of an educational revolution. Clustered in small groups, Clark's students are engaged in a hands-on analysis of two competitive cell phone plans. Because all of the students have in hand a Dell Axim with **MRI Graphing Calculator** software, they're able to tackle the problem at their own pace and in their own way. With this powerful combination of hardware and software, Clark has transformed his classroom into an active mathematics "laboratory."

Clark and his colleagues have been work-

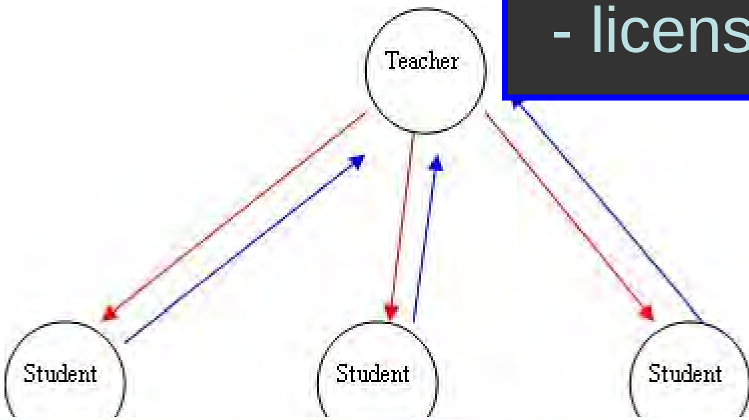
The effect of the new technology on Clark's teaching style has been dramatic. Previously he used up to a third of his class time just explaining how to work the calculator and guiding students step by step through complicated keystrokes. Now he focuses entirely on how to work the problems: he's free to engage students in what he calls "discovery learning." In some cases, he's able to cover a concept twice as quickly as it would have taken in the past.

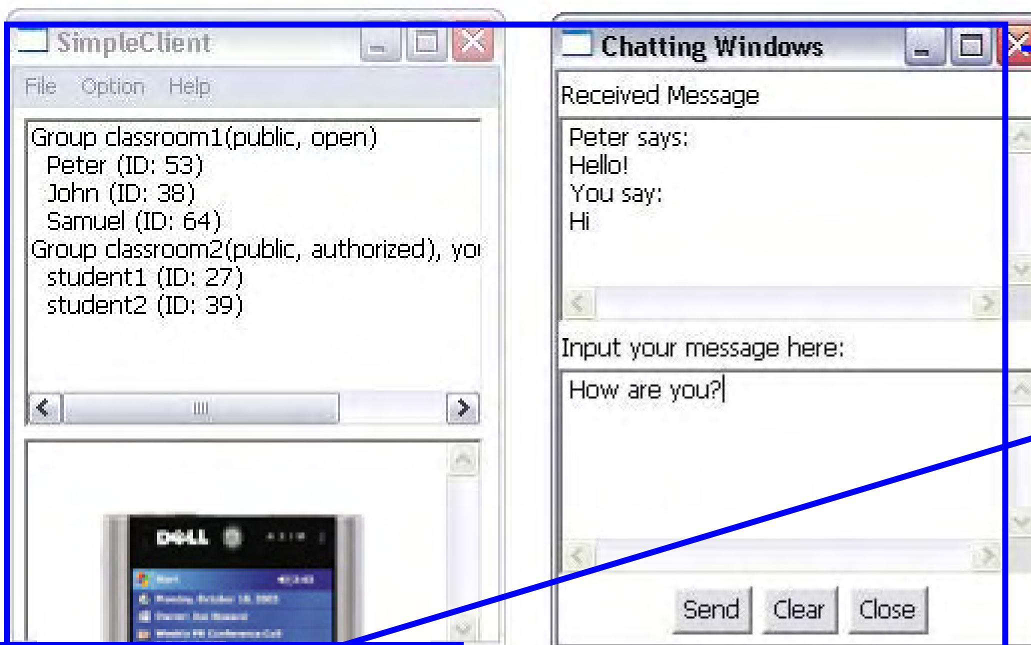
Clark says that MRI Graphing Calculator and Pocket PCs have sharpened the focus of his teaching. "Just the fact that a handheld computer displays colors is huge," he notes, "especially when you are working with a problem that involves plotting and compar-

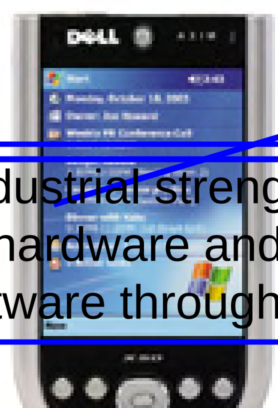


Prototyping Collaboration

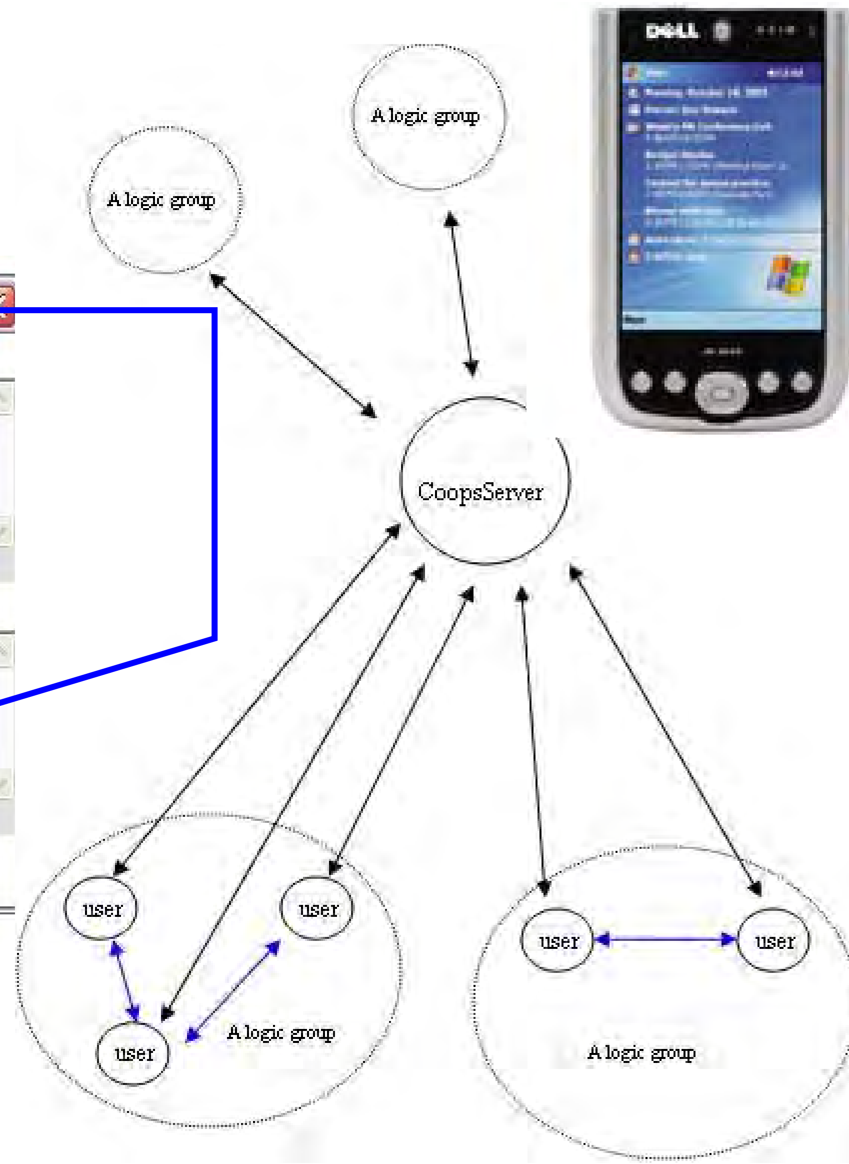
- licenses, permissions, privacy, security etc







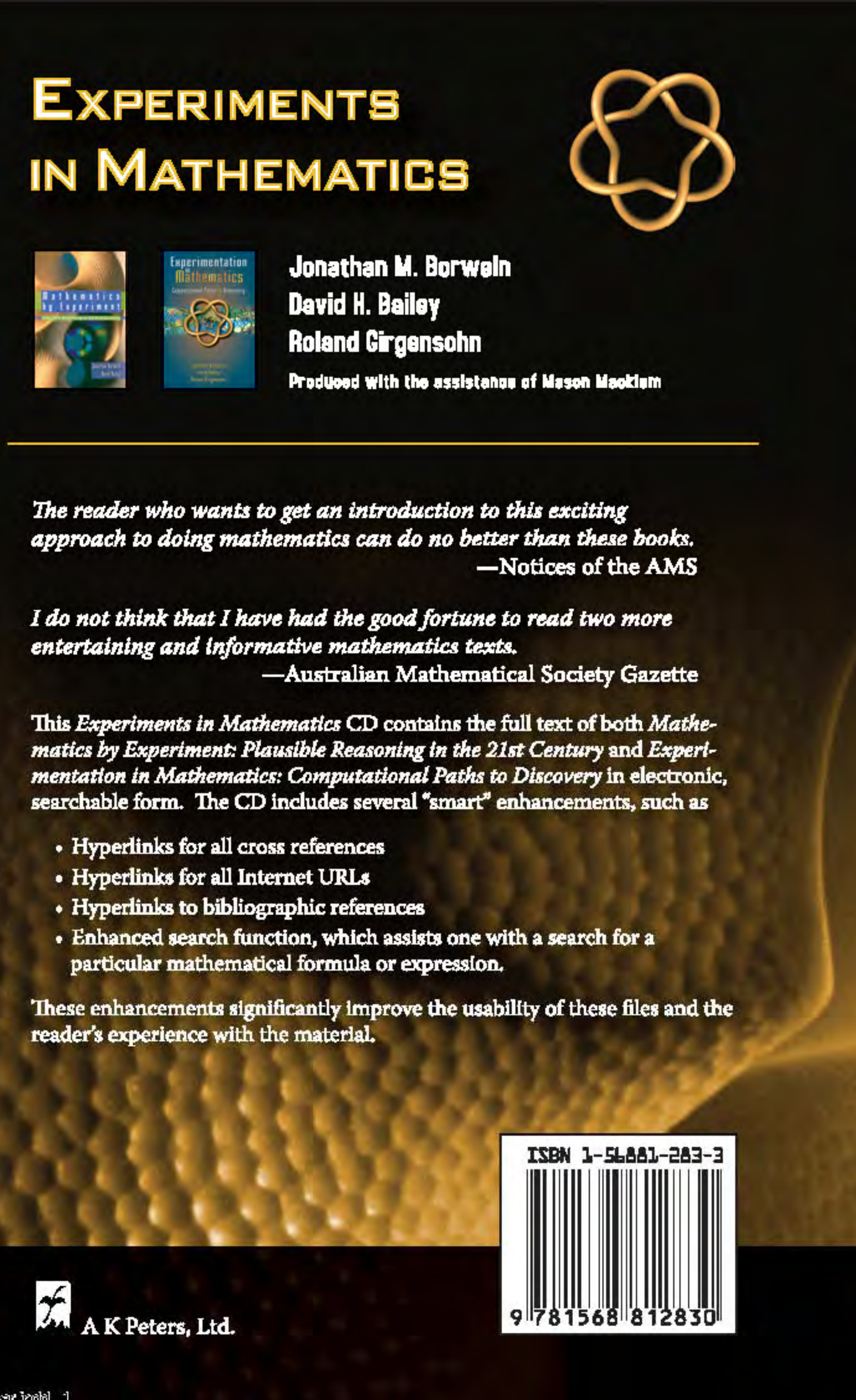
Industrial strength hardware and software throughout

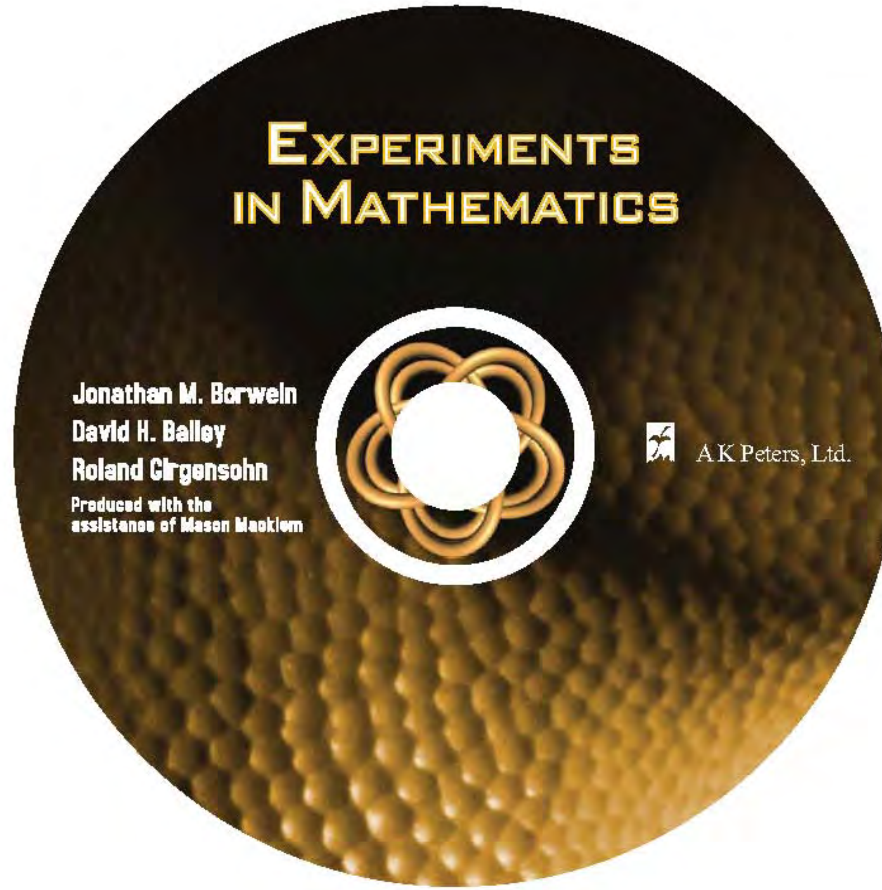


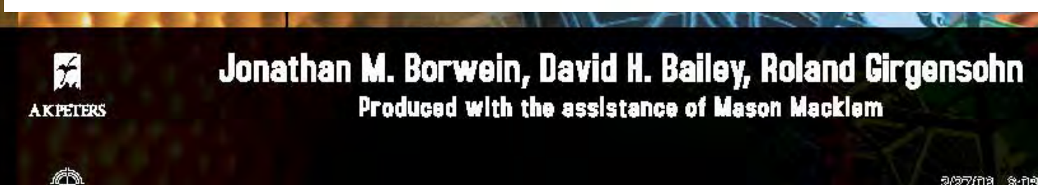
"It says it's sick of doing things like inventories and payrolls, and it wants to make some breakthroughs in astrophysics."

Newly Published as CD

SELF ADVERTISEMENT

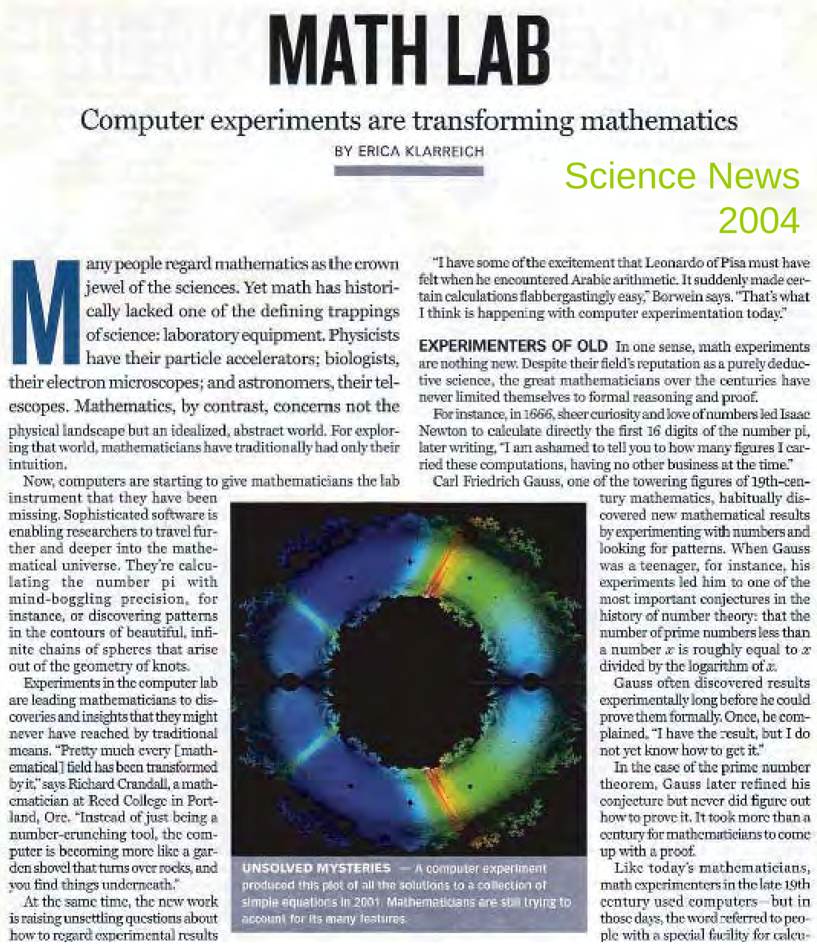






Experimental Mathodology

1. Gaining insight and intuition
2. Discovering new relationships
3. Visualizing math principles
4. Testing and especially falsifying conjectures
5. Exploring a possible result to see if it merits formal proof
6. Suggesting approaches for formal proof
7. Computing replacing lengthy hand derivations
8. Confirming analytically derived results



MATH LAB

Computer experiments are transforming mathematics

BY ERICA KLARREICH

Many people regard mathematics as the crown jewel of the sciences. Yet math has historically lacked one of the defining trappings of science: laboratory equipment. Physicists have their particle accelerators; biologists, their electron microscopes; and astronomers, their telescopes. Mathematics, by contrast, concerns not the physical landscape but an idealized, abstract world. For exploring that world, mathematicians have traditionally had only their intuition.

Now, computers are starting to give mathematicians the lab instrument that they have been missing. Sophisticated software is enabling researchers to travel further and deeper into the mathematical universe. They're calculating the number pi with mind-boggling precision, for instance, or discovering patterns in the contours of beautiful, infinite chains of spheres that arise out of the geometry of knots.

Experiments in the computer lab are leading mathematicians to discoveries and insights that they might never have reached by traditional means. "Pretty much every [mathematical] field has been transformed by it," says Richard Crandall, a mathematician at Reed College in Portland, Ore. "Instead of just being a number-crunching tool, the computer is becoming more like a garden shovel that turns over rocks, and you find things underneath."

At the same time, the new work is raising unsettling questions about how to regard experimental results

UNSOLVED MYSTERIES — A computer experiment produced this plot of all the solutions to a collection of simple equations in 2001. Mathematicians are still trying to account for its many features.

"I have some of the excitement that Leonardo of Pisa must have felt when he encountered Arabic arithmetic. It suddenly made certain calculations flabbergastingly easy," Borwein says. "That's what I think is happening with computer experimentation today."

EXPERIMENTERS OF OLD In one sense, math experiments are nothing new. Despite their field's reputation as a purely deductive science, the great mathematicians over the centuries have never limited themselves to formal reasoning and proof.

For instance, in 1666, sheer curiosity and love of numbers led Isaac Newton to calculate directly the first 16 digits of the number pi, later writing, "I am ashamed to tell you to how many figures I carried these computations, having no other business at the time."

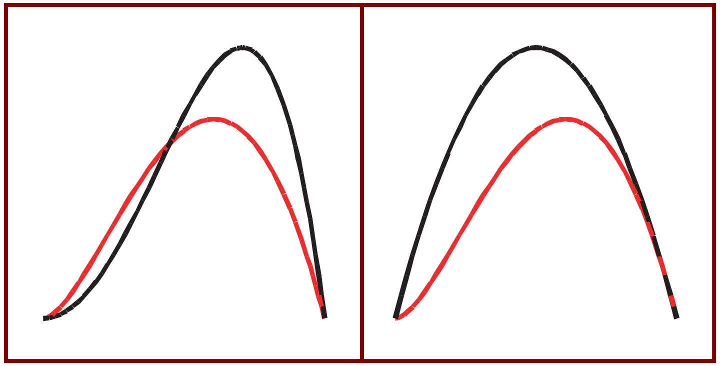
Carl Friedrich Gauss, one of the towering figures of 19th-century mathematics, habitually discovered new mathematical results by experimenting with numbers and looking for patterns. When Gauss was a teenager, for instance, his experiments led him to one of the most important conjectures in the history of number theory: that the number of prime numbers less than a number x is roughly equal to x divided by the logarithm of x.

Gauss often discovered results experimentally long before he could prove them formally. Once, he complained, "I have the result, but I do not yet know how to get it."

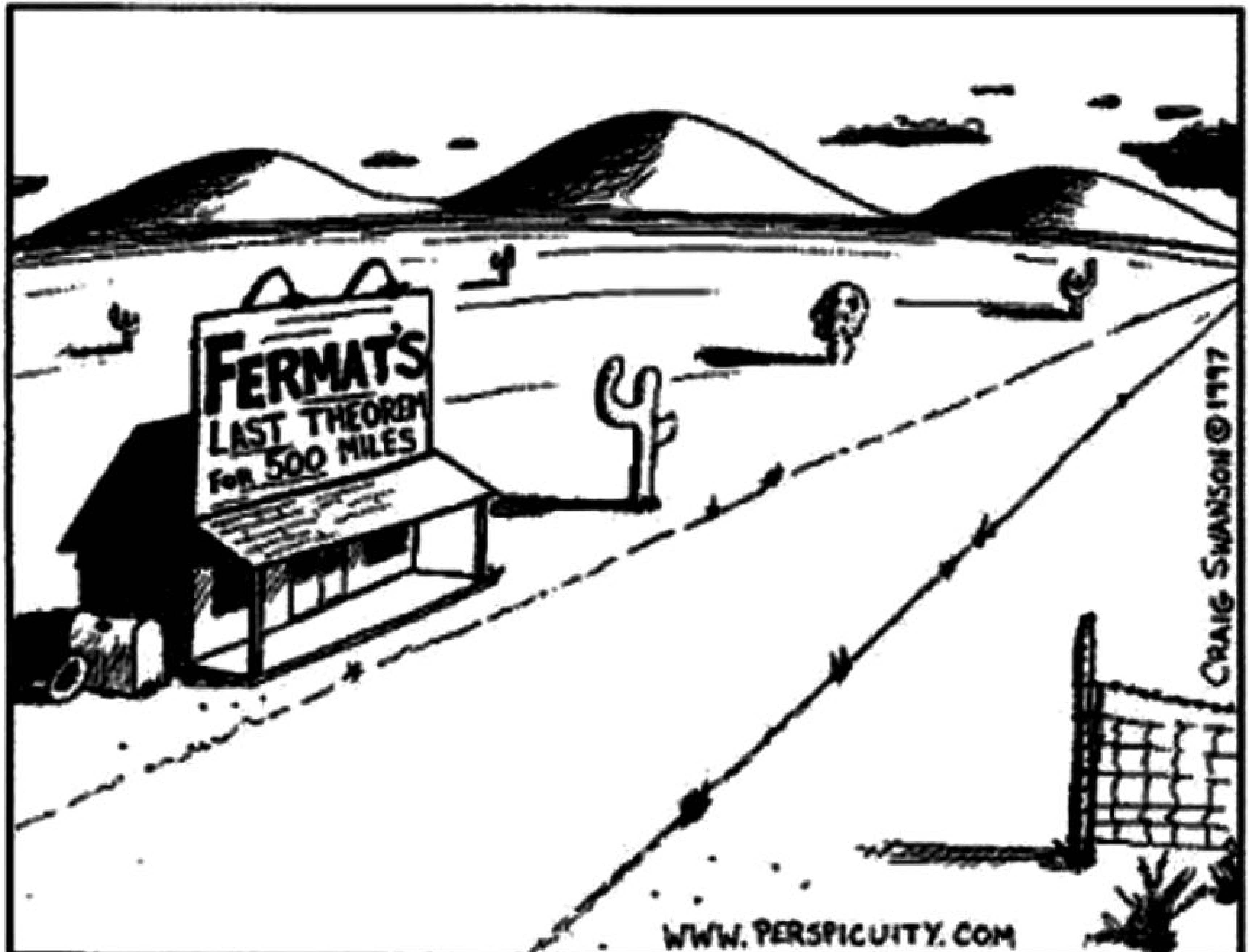
In the case of the prime number theorem, Gauss later refined his conjecture but never did figure out how to prove it. It took more than a century for mathematicians to come up with a proof.

Like today's mathematicians, math experimenters in the late 19th century used computers—but in those days, the word referred to people with a special facility for calcu-

Science News 2004



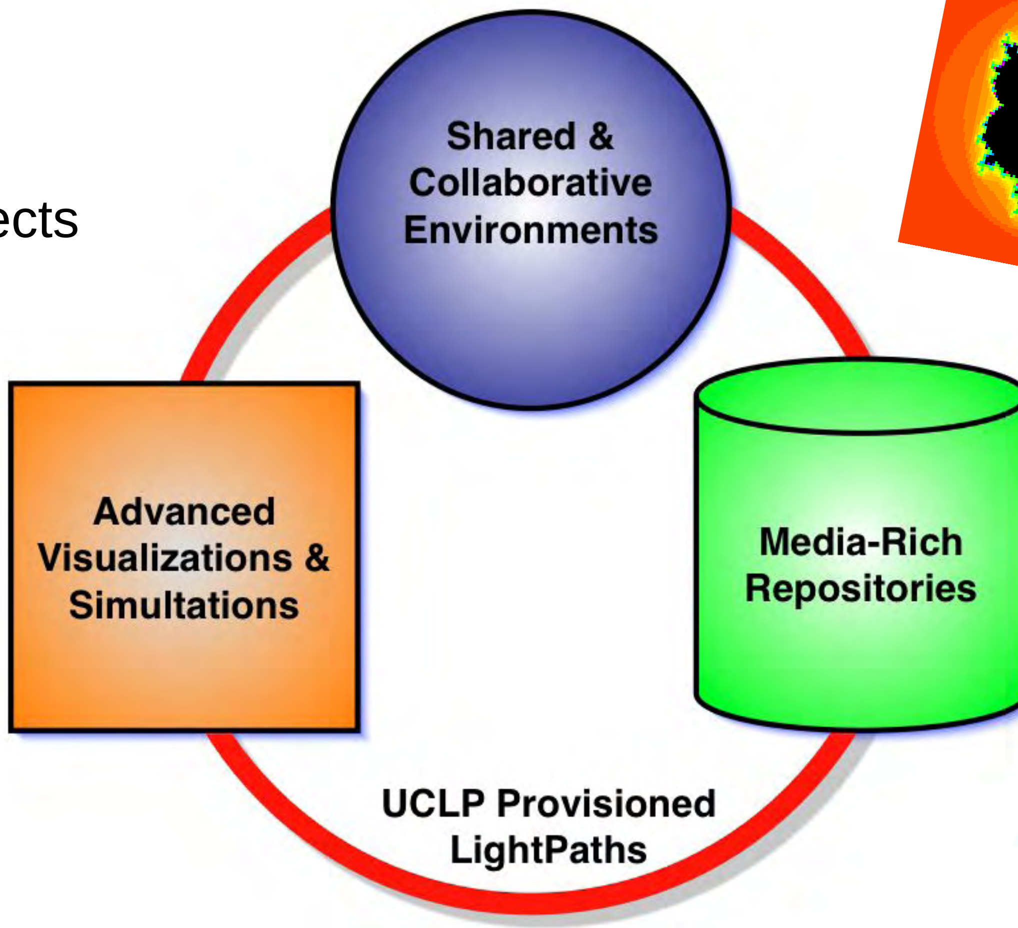
Comparing $-y^2\ln(y)$ (red) to $y-y^2$ and y^2-y^4

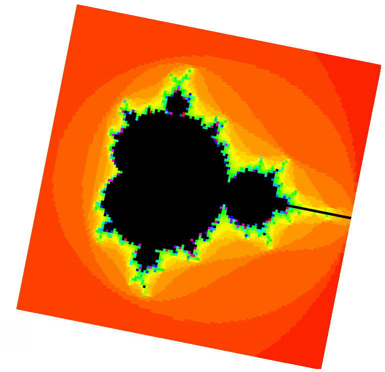

FERMAT'S
LAST THEOREM
FOR 500 MILES
CRAIG SWANSON © 1997
WWW.PERSPICUITY.COM

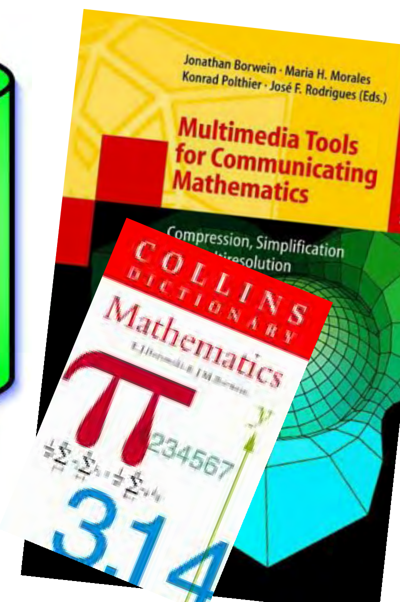
Advanced Networking … (with CANARIE)

Components include

- **AccessGrid**
- **UCLP** for
  - haptics
  - learning objects
  - visualization
- **Grid Computing**
- **Archival Storage**
  - **Data Bases**
  - **Data Mining**







Coast to Coast Seminar Series (C2C)

Tuesdays 3:30 – 4:30 pm Atlantic Time

http://projects.cs.dal.ca/ddrive/

Lead partners:

Dalhousie D-Drive – Halifax Nova Scotia

SFU IRMACS – Burnaby British Columbia

Other Participants so far:

University of British Columbia, University of Alberta, University of Alberta, University of Saskatchewan, Lethbridge University, Acadia University, St Francis Xavier University, MUN, University of Western Michigan, MathResources Inc, University of North Carolina

Dalhousie Distributed Research Institute and Virtual Environment

The Experience

Fully Interactive multi-way audio and video

audio is harder (given good bandwidth)

The closest thing to being in the same room

Shared Desktop for viewing presentations or sharing software

Virtual CoLab at SFU

(adding architectural metaphors)

2003: <u>Me and my Avatar</u>
- designer now works for
William Shatner ('Wild')

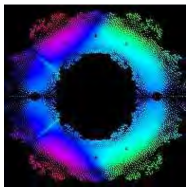
The 2,500 sq-metre **IRMACS** research centre

Trans-Canada ‘C2C’ Seminar
Tuesdays PST 11.30 MST 12.30 AST 3.30 and even 7.30 GMT
[March 30 – from MRInc]

SFU building is a also a 190cpu G5 Grid

At the official April 2005 opening, I gave one of the four presentations from D-DRIVE

High Quality Presentations



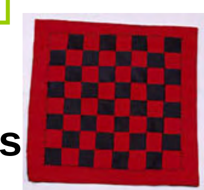
Jonathan Borwein, Dalhousie University
Mathematical Visualization

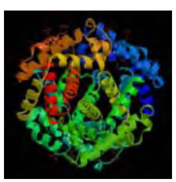
Uwe Glaesser, Simon Fraser University
Semantic Blueprints of Discrete Dynamic Systems

Peter Borwein, IRMACS
The Riemann Hypothesis

"No one explains chalk"

Jonathan Schaeffer, University of Alberta
Solving Checkers





Arvind Gupta, MITACS
The Protein Folding Problem

Przemyslaw Prusinkiewicz, University of Calgary
Computational Biology of Plants

Karl Dilcher, Dalhousie University
Fermat Numbers, Wieferich and Wilson Primes

Haptics in the MLP

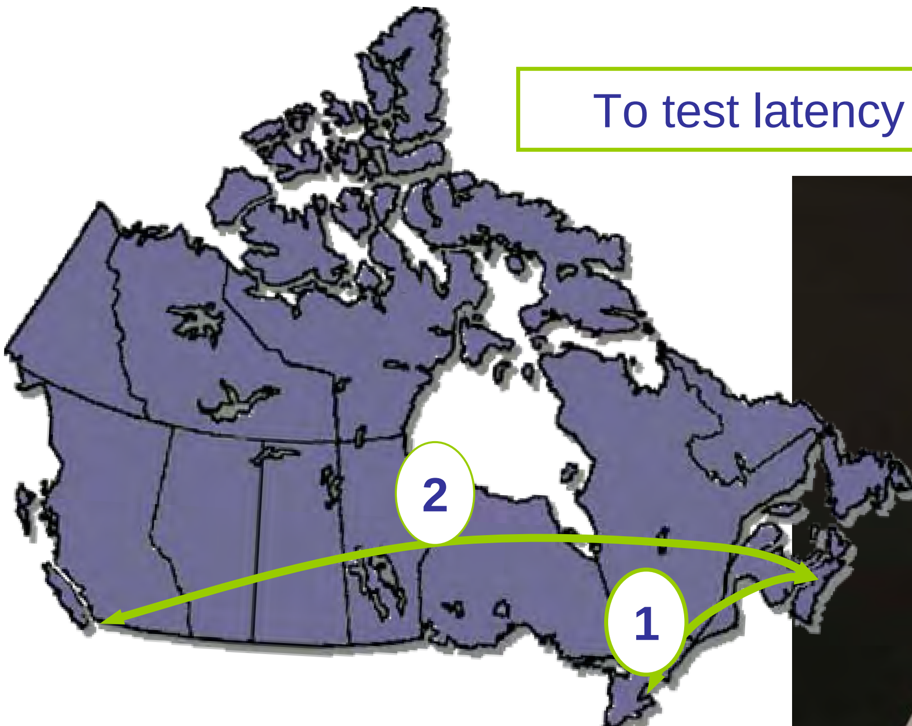
D-DRIVE Doug our haptic mascot

Drive

Dalhousie Distributed Research Institute and Virtual Environment

Haptic Devices extend the world of I/O into the tangible and tactile

To test latency issues …



We link multiple devices so two or more users may interact at a distance (**BC/NS Demo** April 06)

- in Museums and elsewhere
- Kinesiology, Surgery, Music, Art …

Sensable's **Phantom Omni**

"What I appreciate even more than its remarkable speed and accuracy are the words of understanding and compassion I get from it."

Outline of ACE Talk

A. Communication, Collaboration and Computation.

B1. Visual Data Mining in Mathematics (old and new).

B2. Integer Relation Methods.

B3. Inverse Symbolic Computation.

The talk ends when I do

Global digitization efforts are underway within the
International Mathematical Union
www.wdml.org

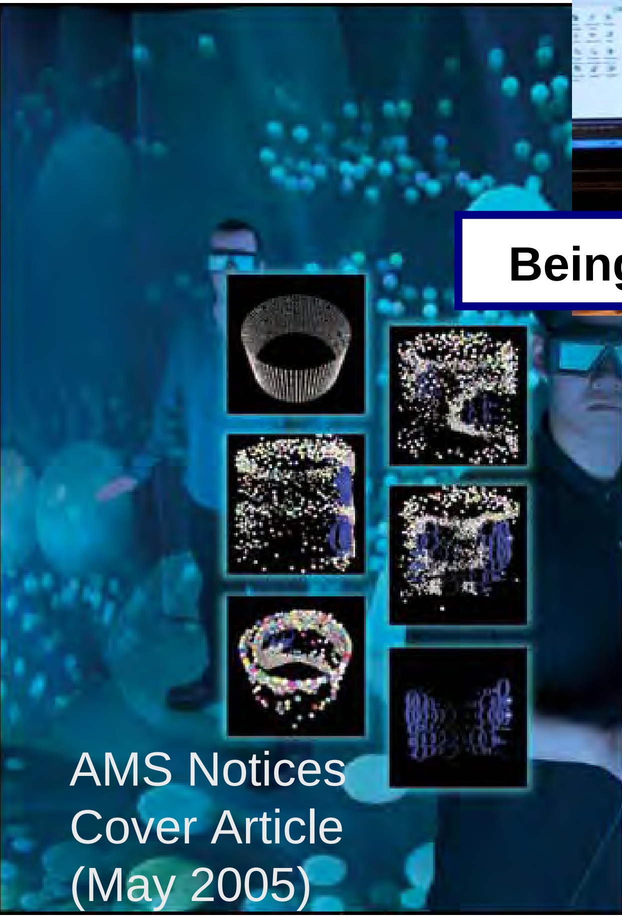
WDML
world digital mathematics library

CMS with **Google**

Drive

5 Smart Shared-Screens

Being emulated by Canadian Kandahar mission



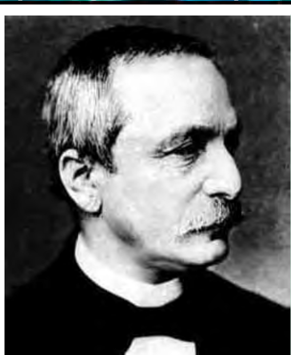
I shall show a variety of mathematical uses of high performance computing and communicating as part of

Experimental Inductive Mathematics

Our web site:

www.experimentalmath.info

contains all links and references



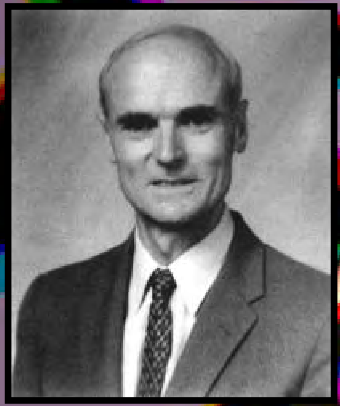
"Elsewhere Kronecker said ``In mathematics, I recognize true scientific value only in concrete mathematical truths, or to put it more pointedly, only in mathematical formulas." ... I would rather say ``computations" than ``formulas", but my view is essentially the same."

Harold Edwards, *Essays in Constructive Mathematics*, 2004

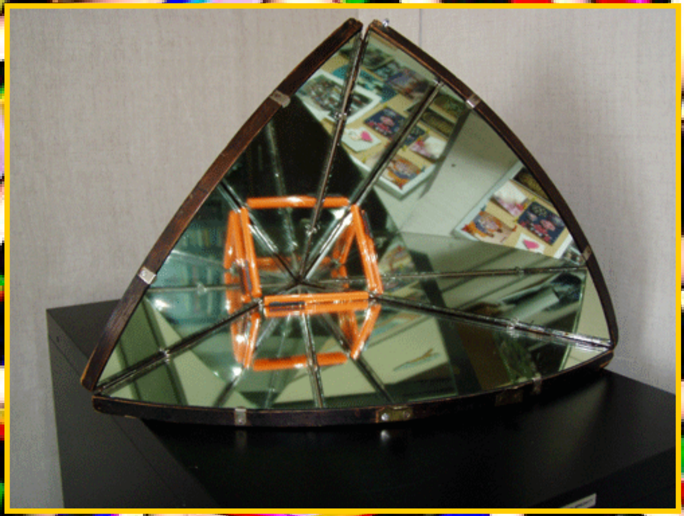

Caveman
Geometry
(2001)
Very cool for the one person with control

COXETER'S (1927) Kaleidescope

Visualization

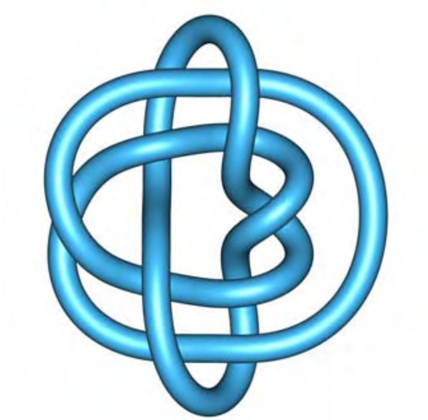


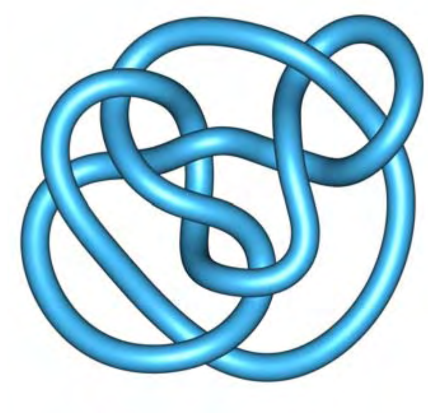
(1907-2003)



The Perko Pair 10_{161} and 10_{162}

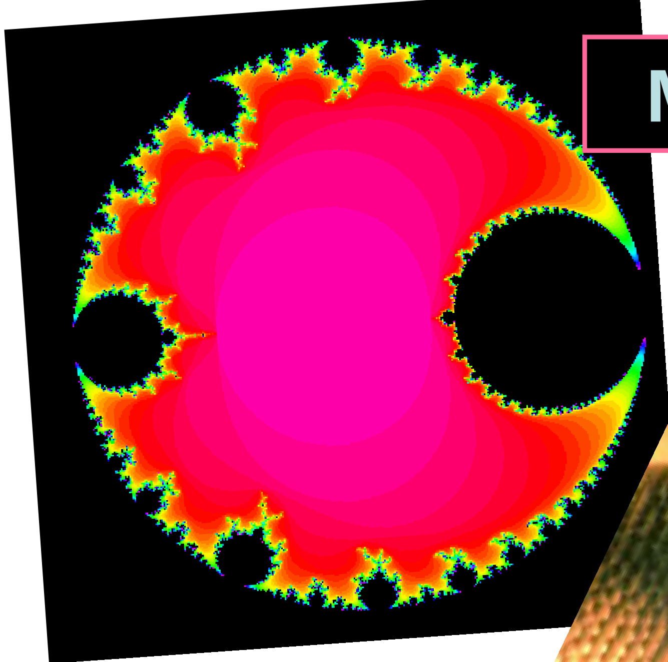
are two adjacent 10-crossing knots (1900)



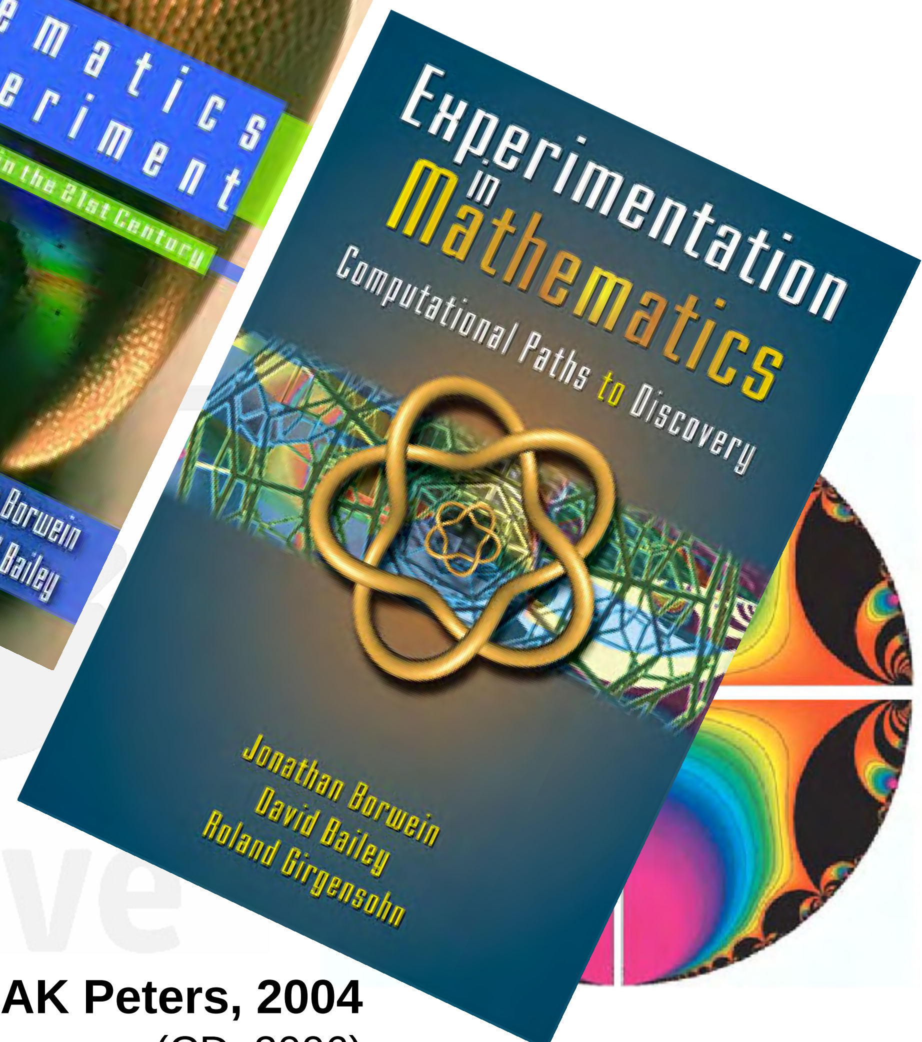


- first shown to be the same by **Ken Perko in 1974**
- and beautifully made dynamic in **KnotPlot** (open source)

More Mathematical Data Mining



An unusual Mandelbrot parameterization



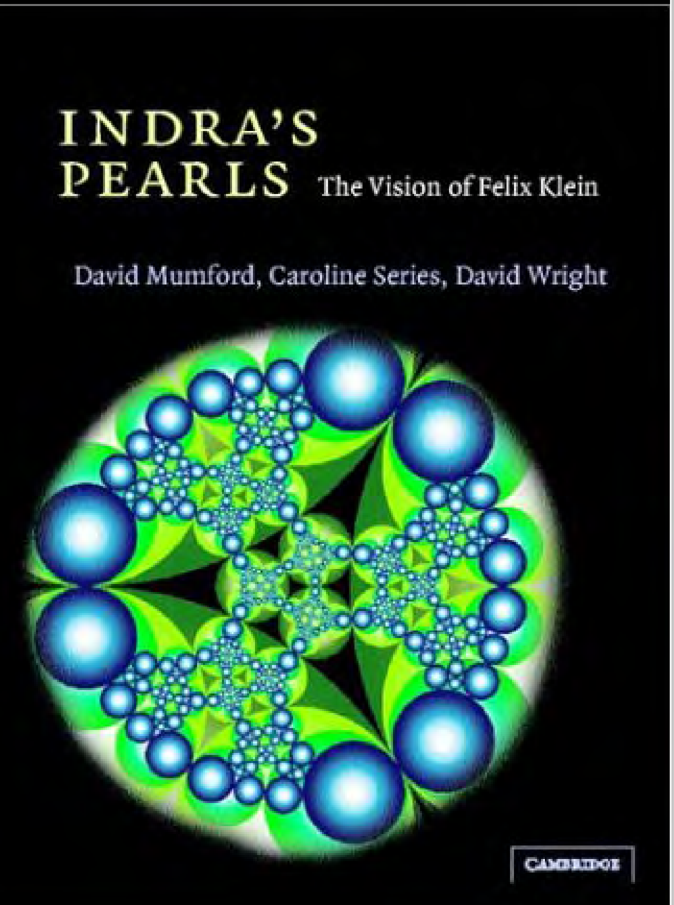
Various visual examples follow

- Indra's pearls
- Roots of `1/-1' polynomials
- Ramanujan's fraction

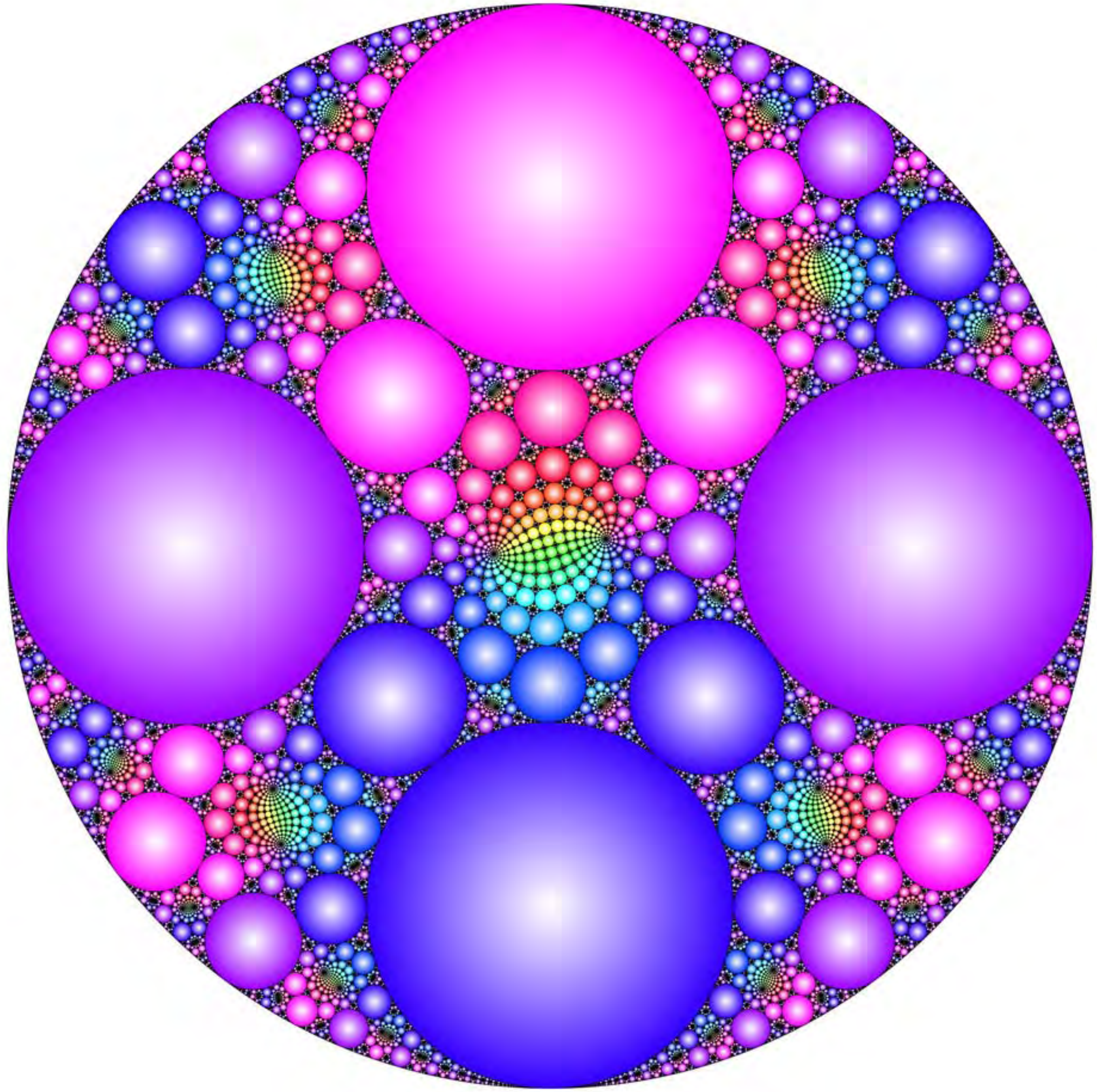
AK Peters, 2004

(CD, 2006)

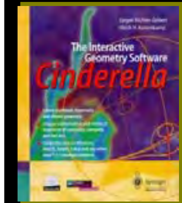
Indra's Pearls
A merging of 19th and 21st Centuries



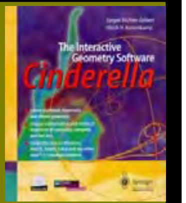
Double cusp group

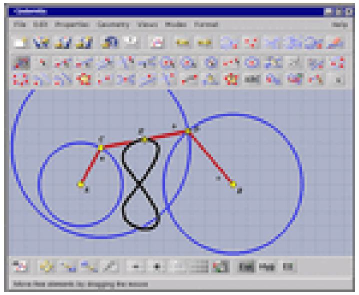


2002: http://klein.math.okstate.edu/IndrasPearls/



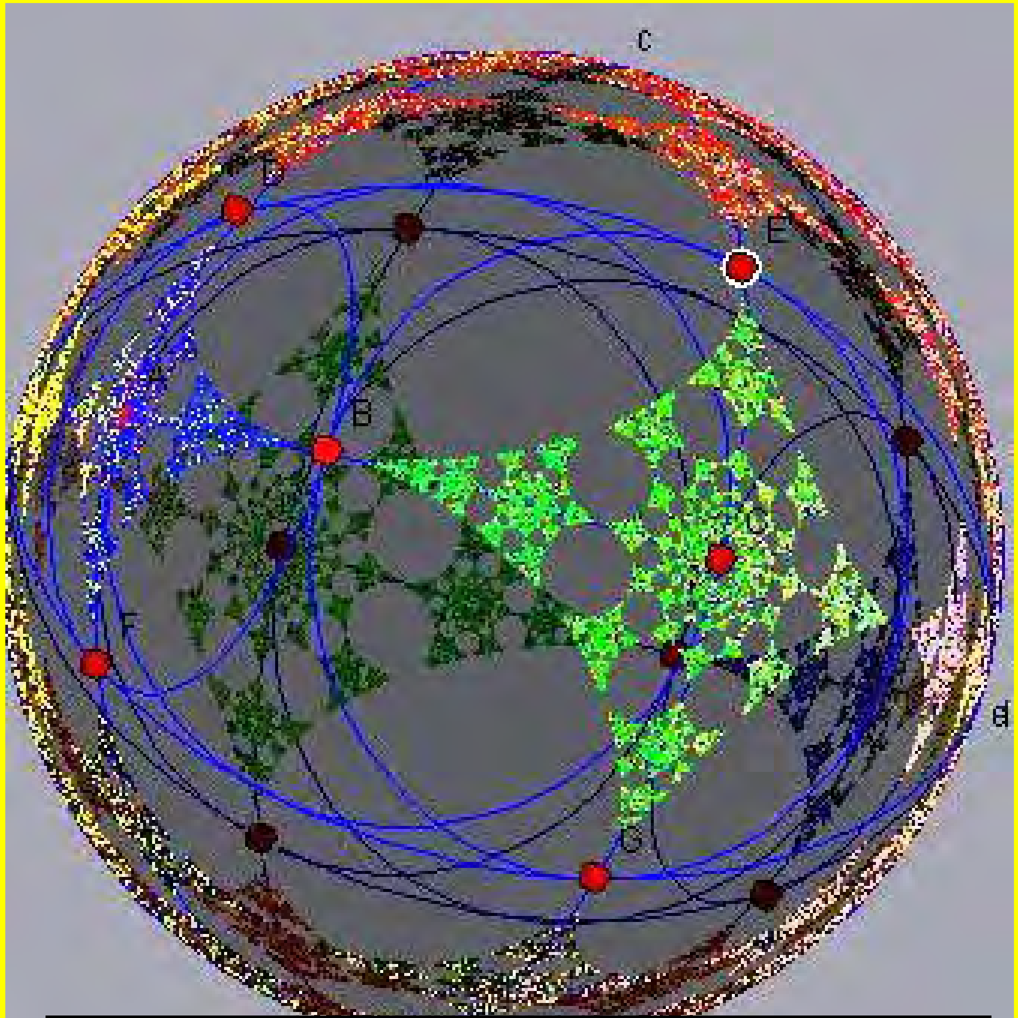
CINDERELLA



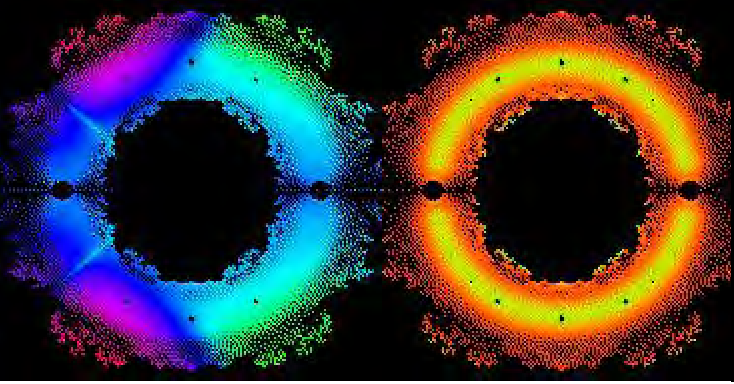


FOUR DEMOS combining inversion, reflection and dilation

1. [Indraspearls]
2. [Apollonius]*
3. [Hyperbolicity]
4. [Gasket]

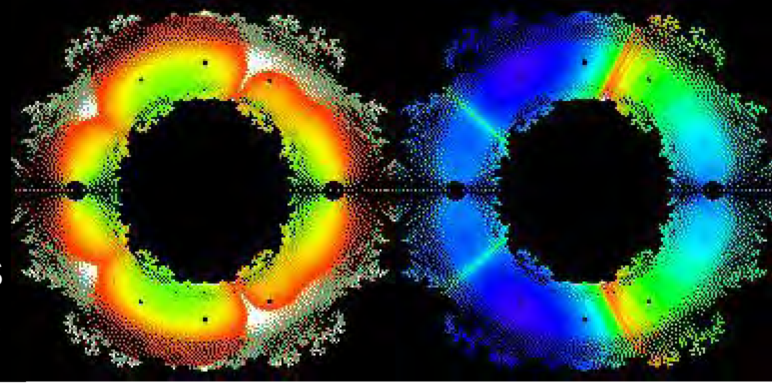


A triangle is now a dynamic object



Roots of Zeros

What you draw is what you see ("visible structures in number theory")



Striking fractal patterns formed by plotting complex zeros for all polynomials in powers of x with coefficients 1 and -1 to degree 18

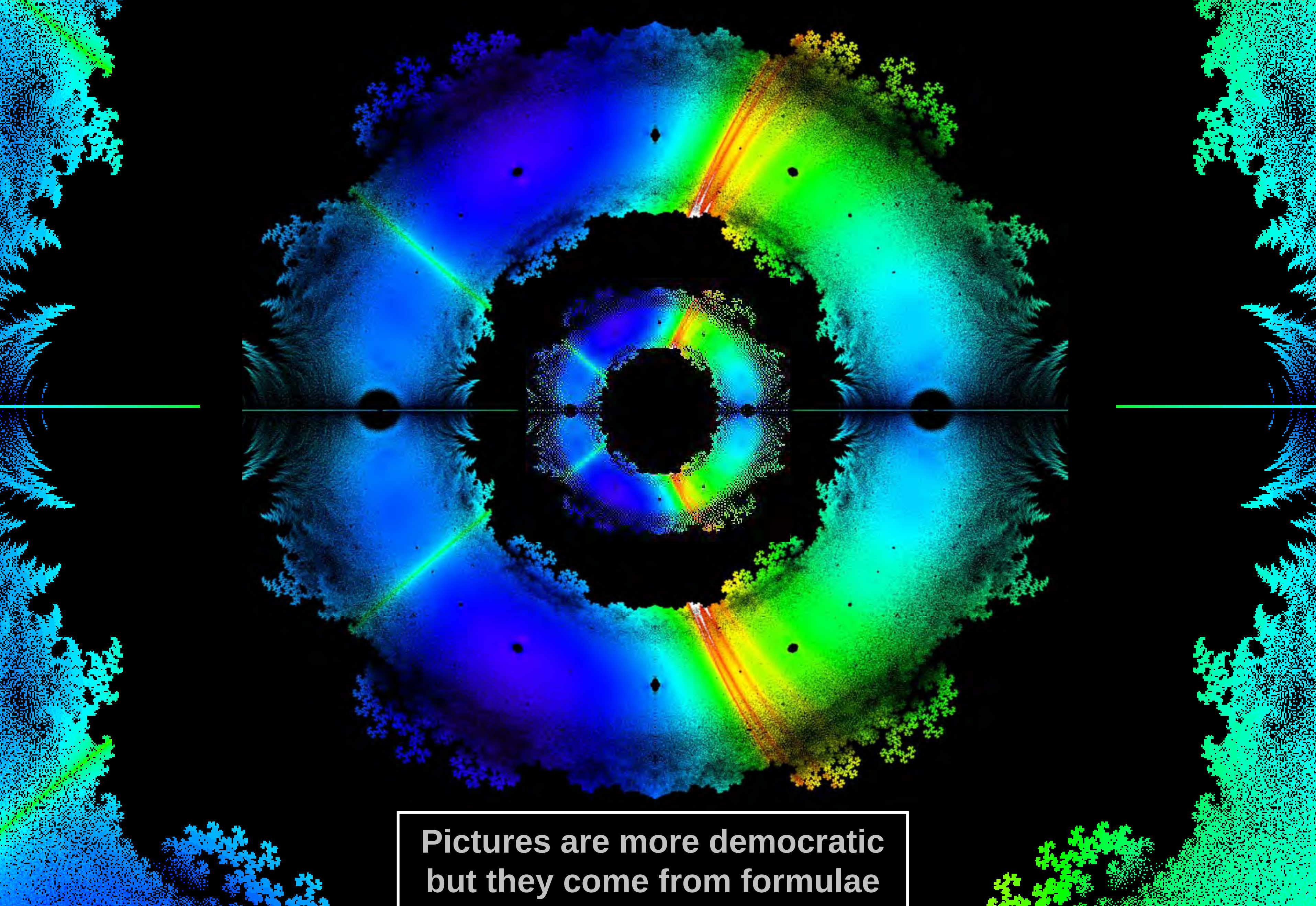
Coloration is by sensitivity of polynomials to slight variation around the values of the zeros. **The color scale represents a normalized sensitivity** to the range of values; red is insensitive to violet which is strongly sensitive.

- All zeros are pictured (at **3600 dpi**)
- Figure 1b is colored by their local density
- Figure 1d shows sensitivity relative to the $\mathbf{x^9}$ term
- **The white and orange striations are not understood**

A wide variety of patterns and features become visible, leading researchers to totally unexpected mathematical results

> *"The idea that we could make biology mathematical, I think, perhaps is not working, but what is happening, strangely enough, is that maybe mathematics will become biological!"* Greg Chaitin, Interview, 2000.

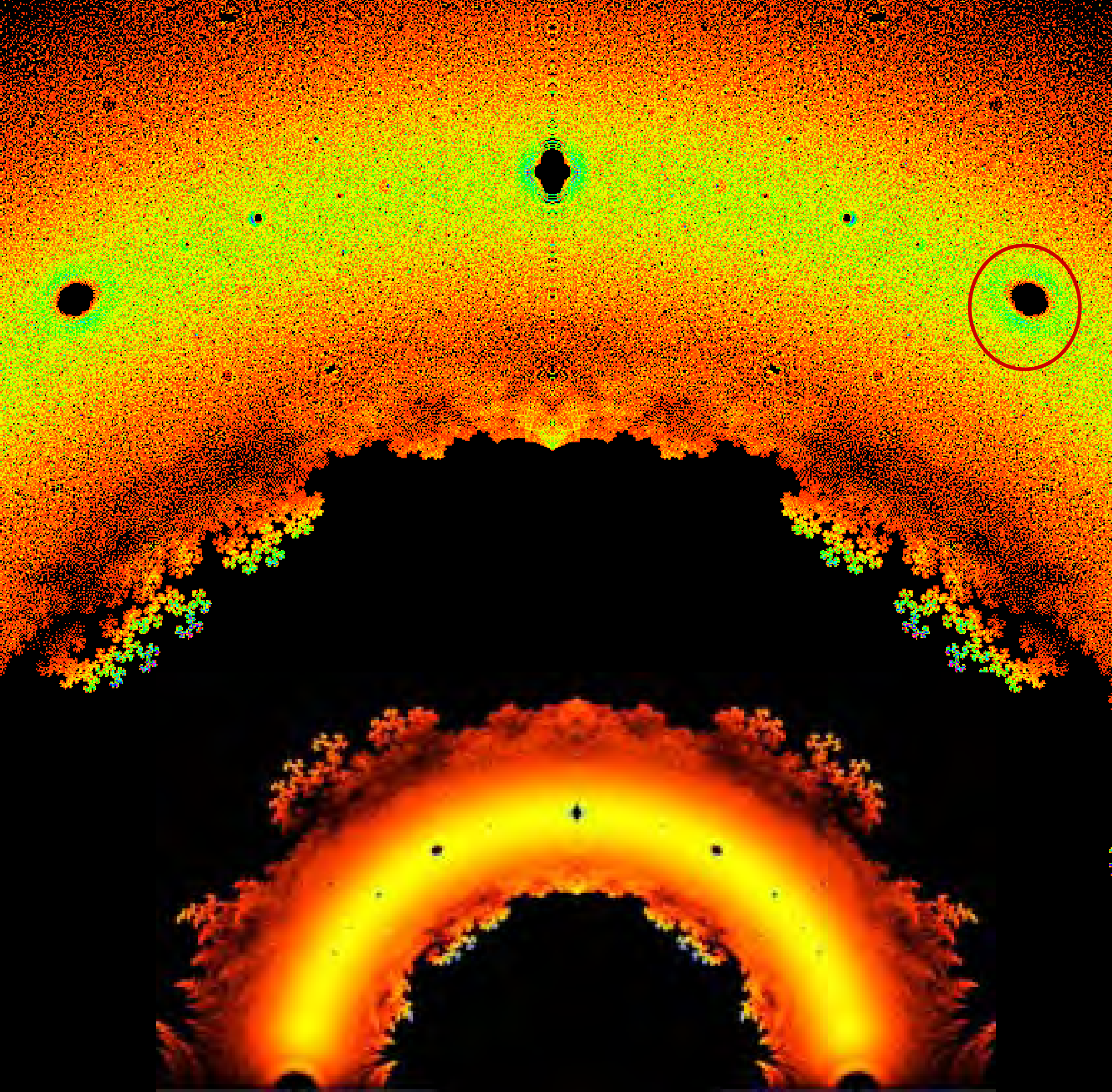
The TIFF on VARIOUS SCALES

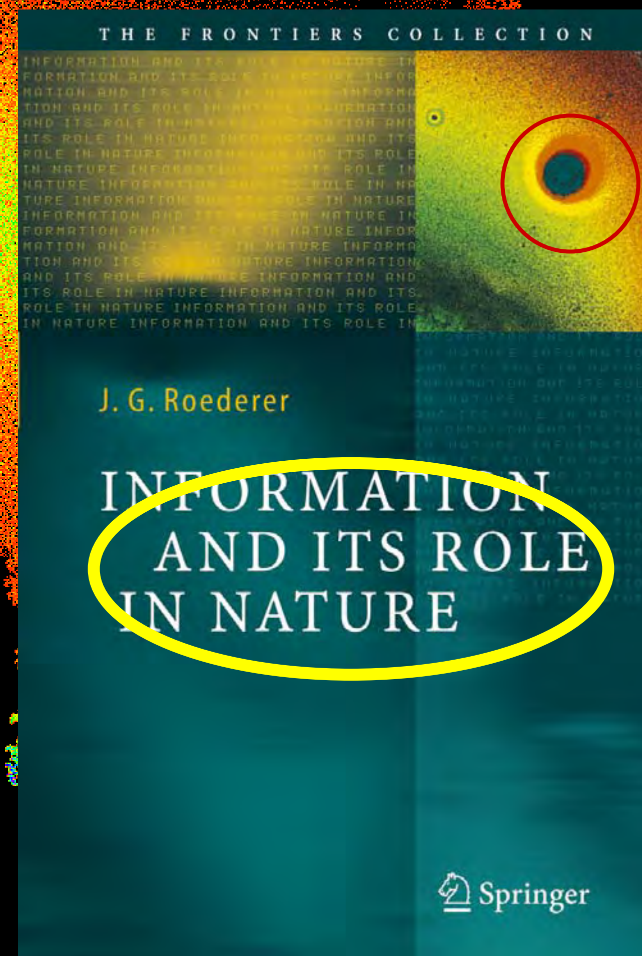


Pictures are more democratic but they come from formulae

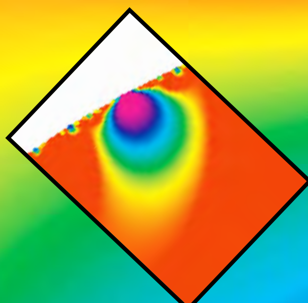
Roots in the most stable colouring

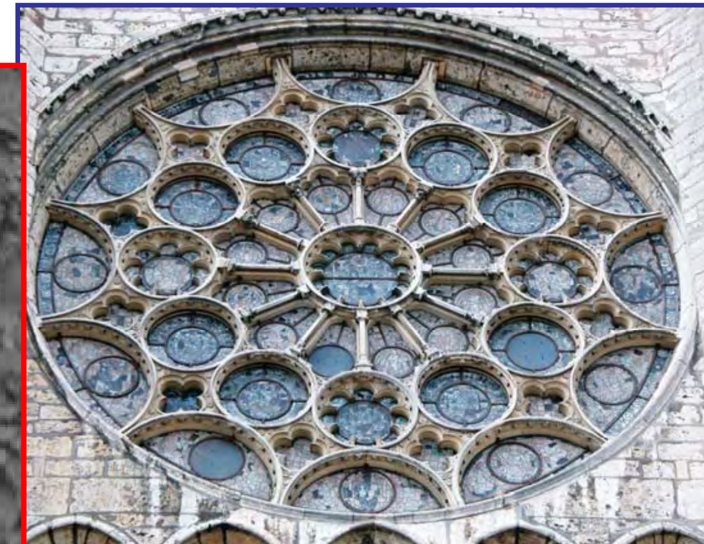
(The Sciences of the Artificial, Simons)





“Mathematics and the aesthetic
Modern approaches to an ancient affinity”
(**CMS-Springer**, 2006)





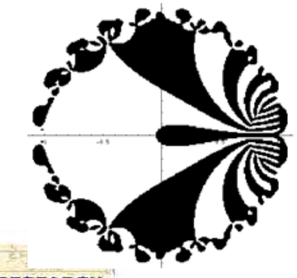
Modular self similarity

Why should I refuse a good dinner simply because I don't understand the digestive processes involved?

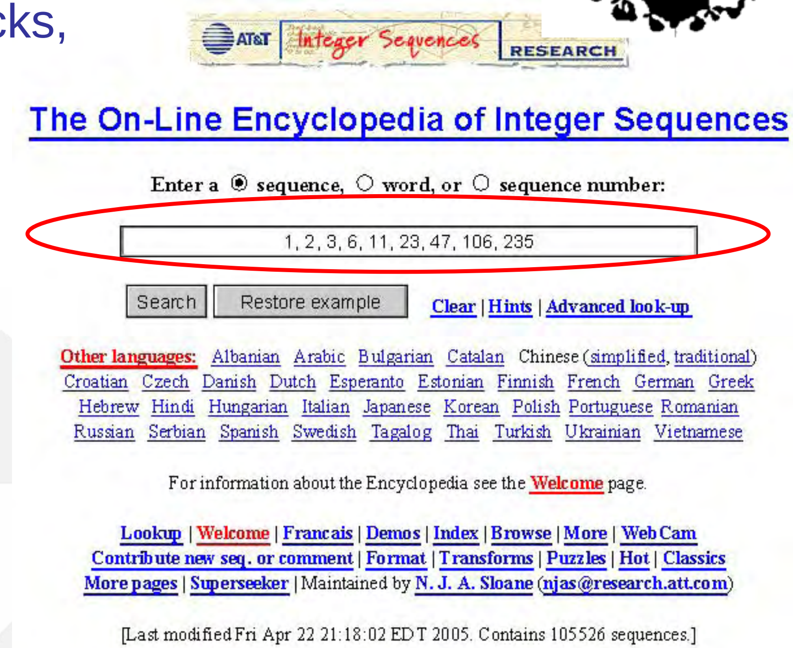
Oliver Heaviside (1850 - 1925)

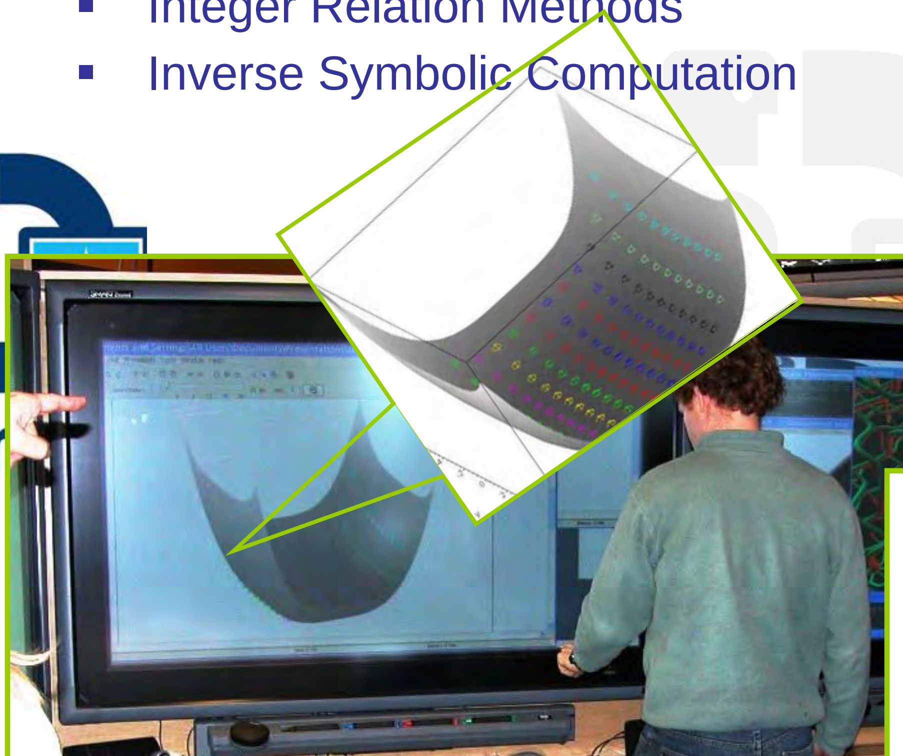
- **when criticized for his daring use of operators before they could be justified formally**

Visual Numeric and Symbolic Computation



- Central to my work - with Dave Bailey - meshed with visualization, randomized checks, many web interfaces/databases **(NIST)**
- Massive (serial) Symbolic Computation
  - Automatic differentiation code
  - Integer Relation Methods
  - Inverse Symbolic Computation





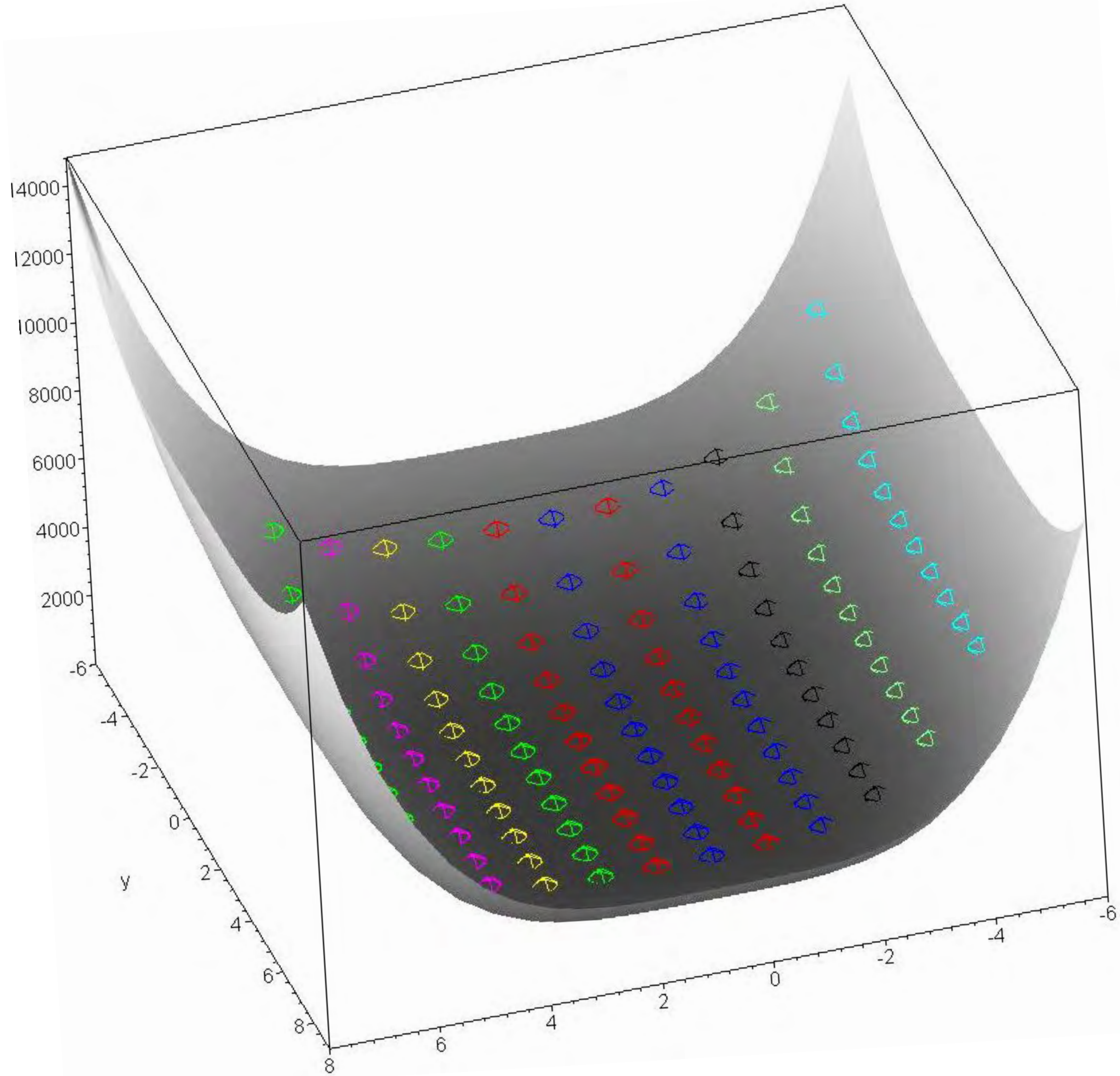
*Parallel derivative free optimization in **Maple***

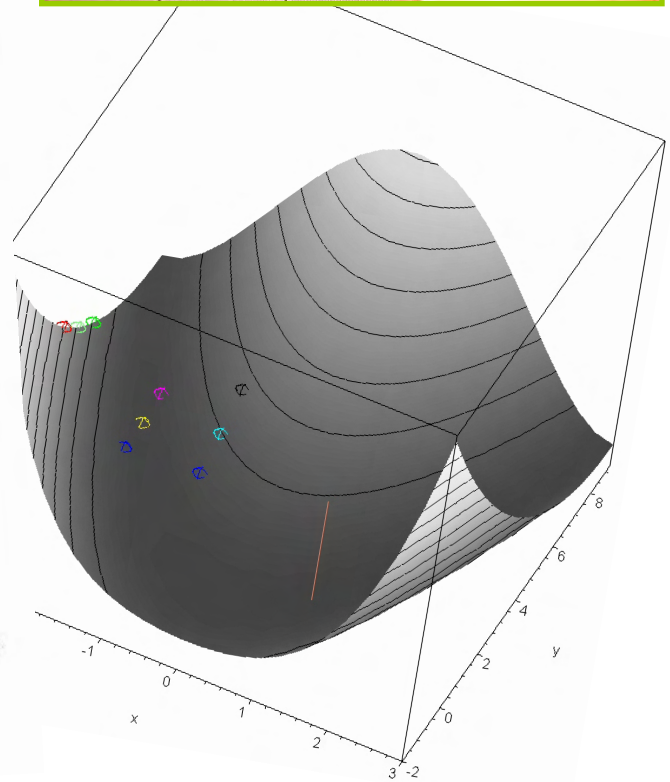
Other useful tools : Parallel Maple

- Sloane's online sequence database
- Salvy and Zimmerman's generating function package '*gfun*'
- Automatic identity proving: Wilf-Zeilberger method for hypergeometric functions

Maple on SFU 192 cpu ‘bugaboo’ cluster

2002 - different node sets are in different colors





http://dlmf.nist.gov (1st 21C database)

Digital Library of Mathematical Functions

Chapter AI. Airy & Related Functions
Properties

- Index
- Notation
- Search

for what [Go]

Show Annotations

Need Help?

About the Project
© Copyright/Privacy Policy
DLMF_feedback@nist.gov
January 12, 2006

Supported by NIST National Institute of Standards and Technology and NSF National Science Foundation Celebrating 50 Years

§AI.3. Graphs & Visualizations | §AI.5. Integral Representations

§AI.4. Maclaurin Series

For $z \in \mathbb{C}$

AI.4.1

$$\mathrm{Ai}(z) = \mathrm{Ai}(0)\left(1 + \frac{1}{3!}z^3 + \frac{1\cdot4}{6!}z^6 + \frac{1\cdot4\cdot7}{9!}z^9 + \cdots\right) + \mathrm{Ai}'(0)\left(z + \frac{2}{4!}z^4 + \frac{2\cdot5}{7!}z^7 + \frac{2\cdot5\cdot8}{10!}z^{10} + \cdots\right)$$

- **Formula level metadata**
- **Mathematical searching**
- **Accessible output**

Symbols used:
AiryAi, cdots and z
A&S Ref:
10.4.2 (with 10.4.4 and 10.4.5)
Encodings:
LaTeX
Parsed:

```
AiryAi@(z) = AiryAi@(0) * (1 + (1 / 3!)
* z ^ 3 + ((1 cdot 4) / 6!) * z ^ 6 +
((1 cdot 4 cdot 7) / 9!) * z ^ 9 +
cdots) + (diffop@(AiryAi, 1))@(0) * (z +
(2 / 4!) * z ^ 4 + ((2 cdot 5) / 7!) * z
^ 7 + ((2 cdot 5 cdot 8) / 10!) * z ^ 10
+ cdots)
```

AI.4.2

$$\mathrm{Ai}'(z) = \mathrm{Ai}'(0)\left(1 + \frac{2}{3!}z^3 + \frac{2\cdot5}{6!}z^6 + \frac{2\cdot5\cdot8}{9!}z^9 + \cdots\right) + \mathrm{Ai}(0)\left(\frac{1}{2!}z^2 + \frac{1\cdot4}{5!}z^5 + \frac{1\cdot4\cdot7}{8!}z^8 + \cdots\right),$$

AI.4.3

$$\mathrm{Bi}(z) = \mathrm{Bi}(0)\left(1 + \frac{1}{3!}z^3 + \frac{1\cdot4}{6!}z^6 + \frac{1\cdot4\cdot7}{9!}z^9 + \cdots\right) + \mathrm{Bi}'(0)\left(z + \frac{2}{4!}z^4 + \frac{2\cdot5}{7!}z^7 + \frac{2\cdot5\cdot8}{10!}z^{10} + \cdots\right)$$

AI.4.4

$$\mathrm{Bi}'(z) = \mathrm{Bi}'(0)\left(1 + \frac{2}{3!}z^3 + \frac{2\cdot5}{6!}z^6 + \frac{2\cdot5\cdot8}{9!}z^9 + \cdots\right) + \mathrm{Bi}(0)\left(\frac{1}{2!}z^2 + \frac{1\cdot4}{5!}z^5 + \frac{1\cdot4\cdot7}{8!}z^8 + \cdots\right).$$

§AI.3. Graphs & Visualizations | §AI.5. Integral Representations

"What it comes down to is our software is too hard and our hardware is too soft."

Outline of ACE Talk

A. Communication, Collaboration and Computation.

B1. Visual Data Mining in Mathematics (old and new).

B2. Integer Relation Methods.

B3. Inverse Symbolic Computation.

The talk ends when I do

IMU Committee on Electronic Information and Communication

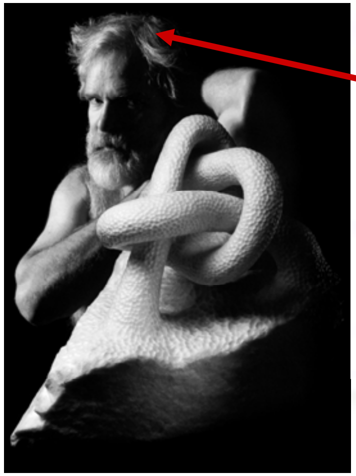
- **Federated Search Tools** are being developed by the **International Mathematical Union (IMU)** www.cs.dal.ca/ddrive/fwdm
- **IMU Best Practices** are lodged at www.ceic.math.ca
- **A Registry of Digital Journals** will be ready soon

Integer Relation Methods

The PSLQ Integer Relation Algorithm

Let (x_n) be a vector of real numbers. An integer relation algorithm finds integers (a_n) such that

$$a_1x_1 + a_2x_2 + \cdots + a_nx_n = 0$$



- At the present time, the PSLQ algorithm of mathematician-sculptor Helaman Ferguson is the best-known integer relation algorithm.
- PSLQ was named one of ten "algorithms of the century" by *Computing in Science and Engineering*.
- High precision arithmetic software is required: at least d x n digits, where d is the size (in digits) of the largest of the integers a_k.

An Immediate Use

To see if a is algebraic of degree N, consider $(1,a,a^2,\dots,a^N)$

Peter Borwein in front of Helaman Ferguson's work

CMS Meeting
December 2003
SFU Harbour Centre

Ferguson uses high tech tools and micro engineering at NIST to build monumental math sculptures

PSLQ and Zeta

Euler (1707-73)

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s}$$

1. via PSLQ to 50,000 digits (250 terms)

$$= \frac{\pi^2}{6}, \zeta(4) = \frac{\pi^4}{90}, \zeta(6) = \frac{\pi^6}{945}, \cdots$$

2005 Bailey, Bradley & JMB ***discovered and proved*** **- in Maple** - three *equivalent* binomial identities

1

$$\mathcal{Z}(x) = 3\sum_{k=1}^{\infty} \frac{1}{\binom{2k}{k}(k^2-x^2)} \prod_{n=1}^{k-1} \frac{4x^2-n^2}{x^2-n^2}$$
$$= \sum_{k=0}^{\infty} \zeta(2k+2) x^{2k} = \sum_{n=1}^{\infty} \frac{1}{n^2-x^2}$$
$$= \frac{1-\pi x \cot(\pi x)}{2x^2}$$

2

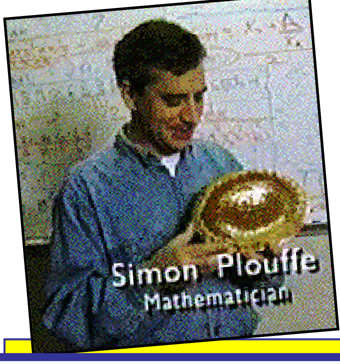
2. reduced as hoped

$$3n^2 \sum_{k=n+1}^{2n} \frac{\prod_{m=n+1}^{k-1} \frac{4\,n^2-m^2}{n^2-m^2}}{\binom{2\,k}{k}\left(k^2-n^2\right)} = \frac{1}{\binom{2\,n}{n}} - \frac{1}{\binom{3\,n}{n}}$$

3

$${}_3F_2\left(\begin{matrix}3n, n+1, -n \\ 2n+1, n+1/2\end{matrix}; \frac{1}{4}\right) = \frac{\binom{2n}{n}}{\binom{3n}{n}}$$

3. was easily **computer proven** (Wilf-Zeilberger)
human proof (MAA)?



PSLQ and Hex Digits of Pi

Finalist for the $100K Edge of Computation Prize won by David Deutsch

$$\log 2 = \sum_{n=1}^{\infty} \frac{1}{k\, 2^k}$$

Edge The Third Culture

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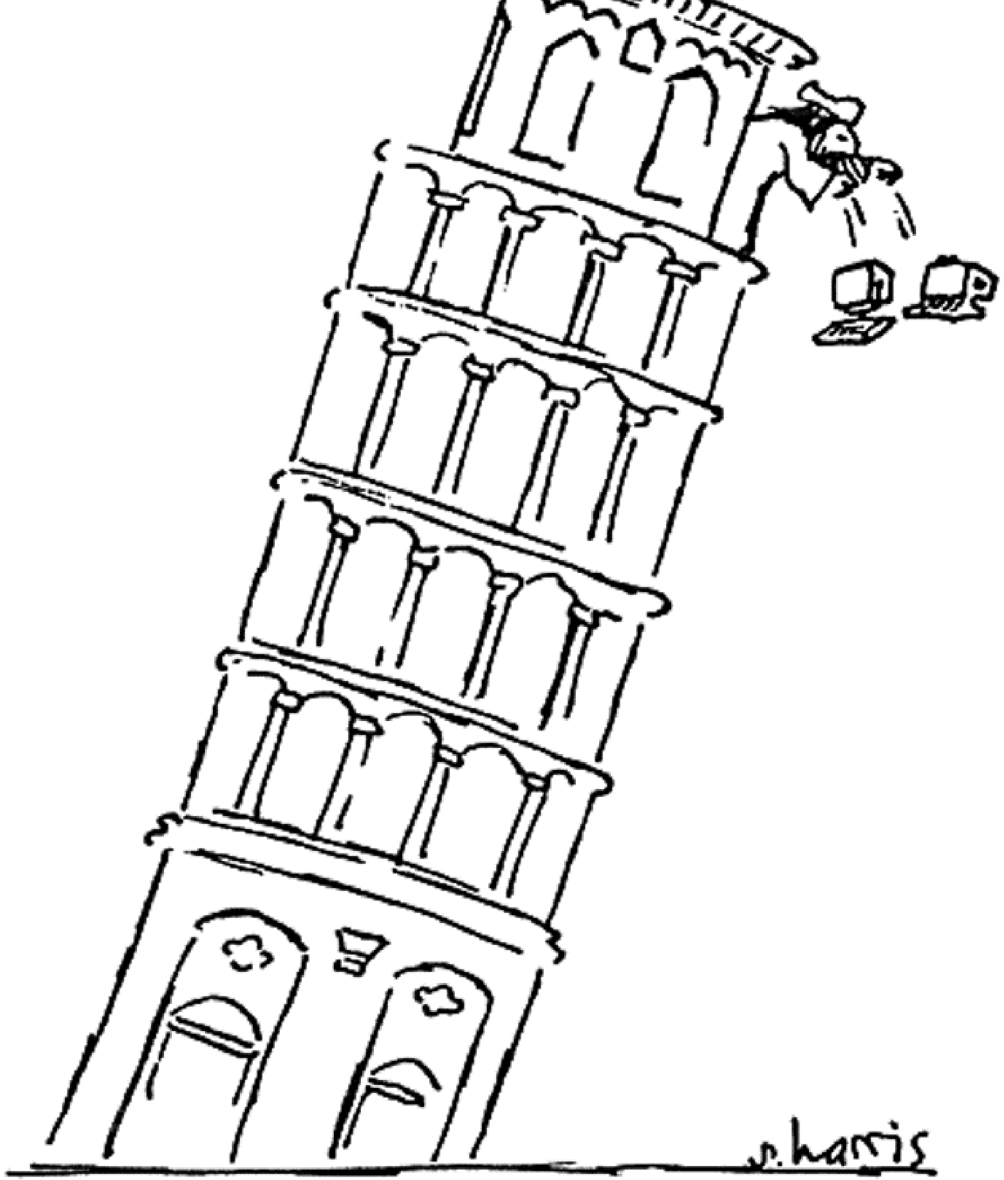
THE $100,000 EDGE OF COMPUTATION SCIENCE PRIZE

For individual scientific work, extending the computational idea, performed, published, or newly applied within the past ten years.

The Edge of Computation Science Prize, established by Edge Foundation, Inc., is a $100,000 prize initiated and funded by science philanthropist Jeffrey Epstein.

No such formula exists base-ten (provably)



IF THERE WERE COMPUTERS IN GALILEO'S TIME

Outline of HPM Talk

A. Communication, Collaboration and Computation.

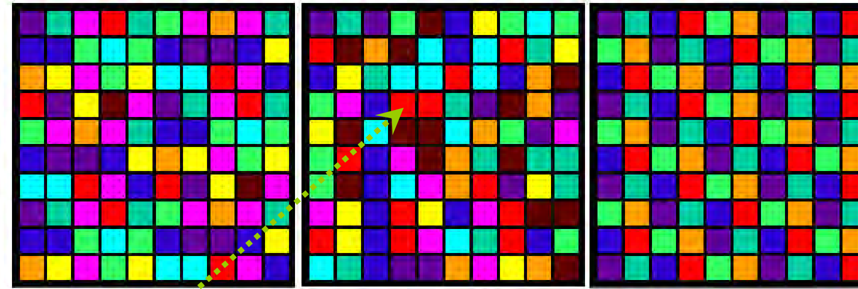
B1. Visual Data Mining in Mathematics (old and new).

B2. Integer Relation Methods.

B3. Inverse Symbolic Computation.

The talk ends when I do

Colour Calculator and Inverse Calculator (1995)



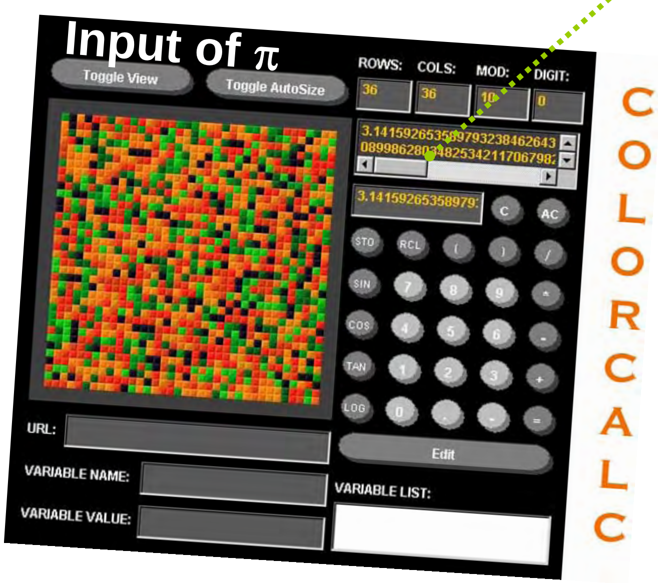
Archimedes: $223/71 < \pi < 22/7$

Inverse Symbolic Computation

Inferring mathematical structure from numerical data

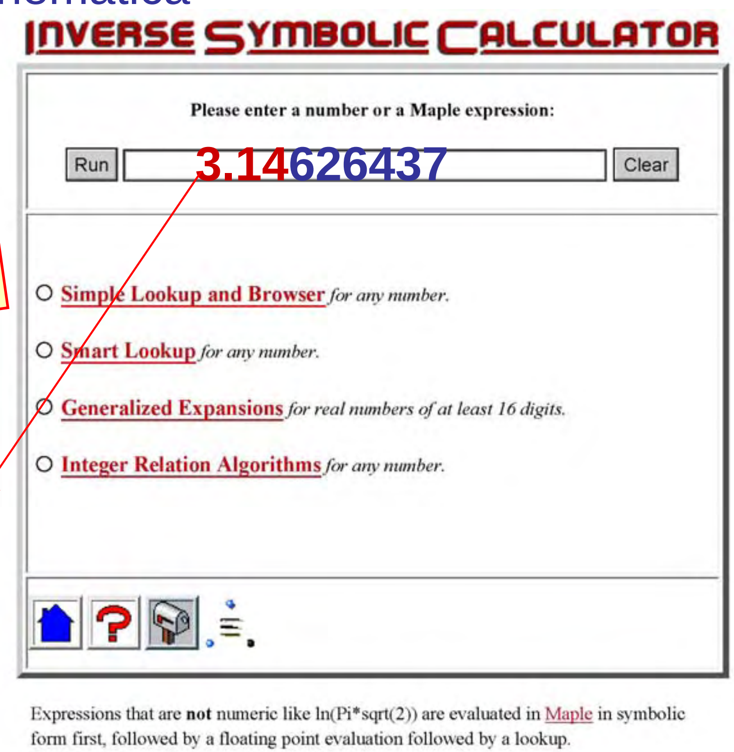
Mixes *large table lookup*, integer relation methods and intelligent preprocessing – needs ***micro-parallelism***

- It faces the “curse of exponentiality”
- Implemented as **Recognize** in Mathematica and **identify** in Maple



identify(sqrt(2.)+sqrt(3.))

$\sqrt{2}+\sqrt{3}$

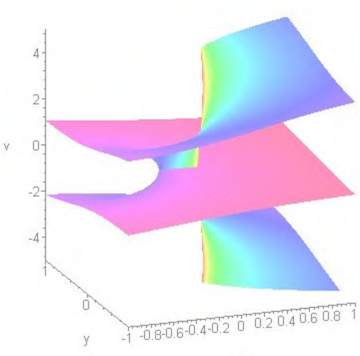


Knuth's Problem

A guided proof followed on **asking WHY** Maple could compute the answer so fast.

The answer is Gonnet's **Lambert's W** which solves

W exp(W) = x

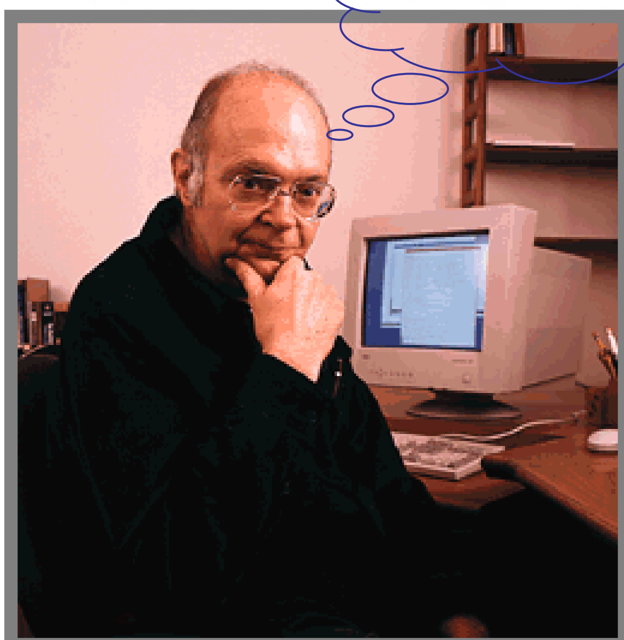


W's **Riemann** surface

Donald Knuth* asked for a closed form evaluation of:

$$\sum_{k=1}^{\infty}\left\{\frac{k^k}{k!\,e^k}-\frac{1}{\sqrt{2\pi k}}\right\}=-0.084069508727655\ldots.$$

"instrumentation"



…sy to compute 20 or 200 digits

ISC is shown on next slide

…kup' facility in the *Inverse Sym-*…

…r† rapidly returns

$$\ldots 508727655 \approx \frac{2}{3}+\frac{\zeta(1/2)}{\sqrt{2\pi}}.$$

We thus have a prediction which *Maple* 9.5 on a laptop confirms to 100 places in under 6 seconds and to 500 in 40 seconds.

*** ARGUABLY WE ARE DONE**

ENTERING

evalf(Sum(k^k/k!/exp(k)-1/sqrt(2*Pi*k),k=1..infinity),16)

'Simple Lookup' fails;
'Smart Look up' gives:

INVERSE SYMBOLIC CALCULATOR

The ISC is the **Inverse Symbolic Calculator**, a set of programs and specialized tables of mathematical constants dedicated to the identification of real numbers. It also serves as a way to produce identities with functions and real numbers. It is one of the main ongoing projects at the Centre for Experimental and Constructive Mathematics (CECM).

Results of the search:

Maple output:

.08406950872765600

.8406950872765600e-1

Value to be looked up: .8406950872765600e-1 = K

Performing a smart lookup on .8406950872765600e-1:

Function	Result	Precision	Matches
K-2/3	.5825971579390106666666666	16	1

...579390106 was probably generated by one ...s or found in one of the given tables.
Answers are given from shortest to longest description

Mixed constants with 5 operations
5825971579390106 = Zeta(1/2)/sr(2)/sr(Pi)

Browse around .5825971579390106.


THEORIES
PROOFS

Outline of ACE Talk

A. Communication, Collaboration and Computation.

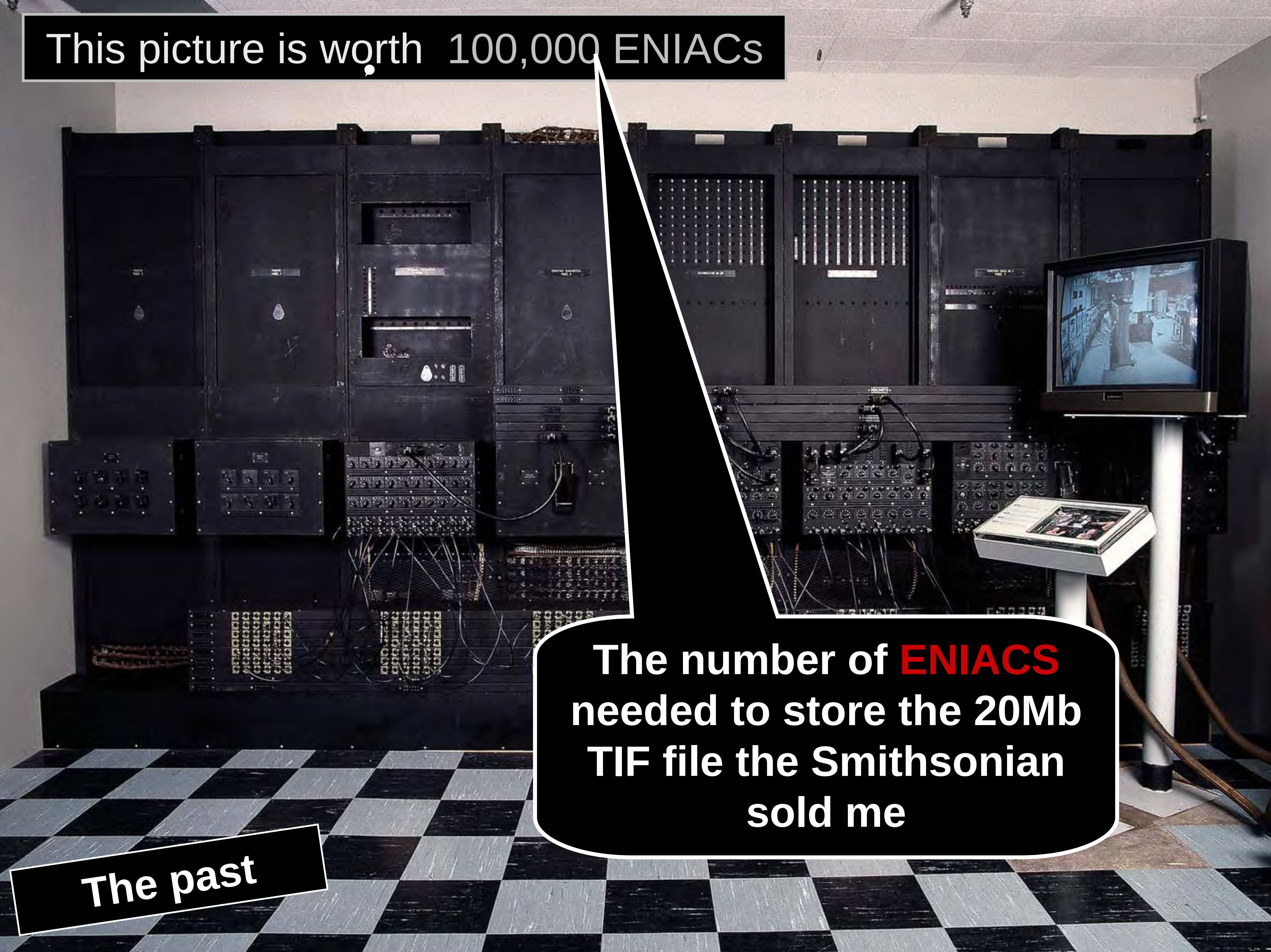
B1. Visual Data Mining in Mathematics (old and new).

B2. Integer Relation Methods.

B3. Inverse Symbolic Computation.

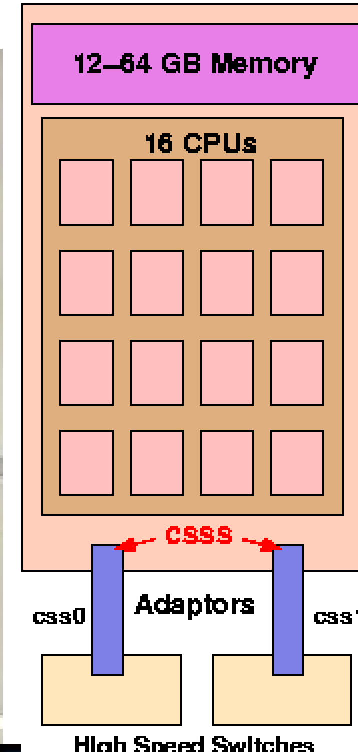
C. Computational Conclusion.

The talk ends when I do


This picture is worth 100,000 ENIACs
The number of ENIACS needed to store the 20Mb TIF file the Smithsonian sold me
The past

NERSC’s 6000 cpu Seaborg in 2004 (10Tflops/sec)

- we need new software paradigms for `bigga-scale’ hardware



The present

Mathematical Immersive Reality
in Vancouver

IBM BlueGene/L system at LLNL

System
(64 cabinets, 64x32x32)

Supercomputer doubles own record

The Blue Gene/L supercomputer has broken its own record to achieve more than double the number of calculations it can do a second.

It reached 280.6 teraflops - that is 280.6 trillion calculations a second.

Blue Gene/L is the fastest computer in the world

5.6/11.2 GF/s
0.5 GB DDR

2.8/5.6 GF/s
4 MB

The future

2^{17} cpu's

Oct 2005 It has now run Linpack benchmark at over **280 Tflop /sec** **(4 x Canadian-REN)**

"Just a darn minute! — Yesterday you said that X equals two!"

CONCLUSION

ENGINES OF DISCOVERY:
The 21st Century Revolution

The Long Range Plan for High Performance Computing in Canada

The LRP tells a Story

- **The Story**
- **Executive Summary**
- **Main Chapters**
  - **Technology**
  - **Operations**
  - **HQP**
  - **Budget**
- **25 Case Studies**
  - **many sidebars**

One Day ...

High-performance computing (HPC) affects the lives of Canadians every day. We can best explain this by telling you a story. It's about an ordinary family on an ordinary day, Russ, Susan, and Kerri Sheppard. They live on a farm 15 kilometres outside Wyoming, Ontario. The land first produced oil, and now it yields milk; and that's just fine locally.

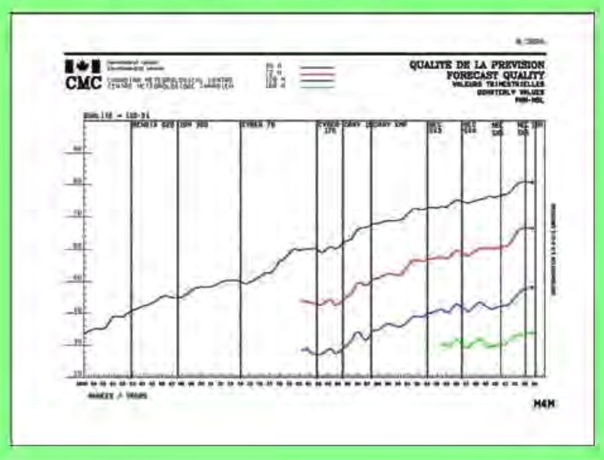
Their day, Thursday, May 29, 2003, begins at 4:30 am when the alarm goes off. A busy day, Susan Zhong-Sheppard will fly to Toronto to see her father, Wu Zhong, at Toronto General Hospital; he's very sick from a stroke. She takes a quick shower and packs a day bag for her 6 am flight from Sarnia's Chris Hadfield airport. Russ Sheppard will stay home at their dairy farm, but his day always starts early. Their young daughter Kerri can sleep three more hours until school.

Waiting, Russ looks outside and thinks, *It's been a dryish spring. Where's the rain?*

In their farmhouse kitchen on a family-sized table sits a PC with a high-speed Internet line. He logs on and finds the Farmer Daily site. He then chooses the Environment Canada link, clicks on Ontario, and then scans down for Sarnia-Lambton.

WEATHER PREDICTION

The "quality" of a five-day forecast in the year 2003 was equivalent to that of a 36-hour forecast in 1963 [REF 1]. The quality of daily forecasts has risen sharply by roughly one day per decade of research and HPC progress. Accurate forecasts transform into billions of dollars saved annually in agriculture and in natural disasters. Using a model developed at Dalhousie University (Prof. Keith Thompson), the Meteorological Service of Canada has recently been able to predict coastal flooding in Atlantic Canada early enough for the residents to take preventative action.



The backbone that makes so much of our Canadian research possible

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J.M. Borwein, D.H. Bailey and R. Girgensohn, *Experimentation in Mathematics: Computational Paths to Discovery,* A.K. Peters, 2004. **[Active CDs 2006]**

D. Bailey, J. Borwein, V. Kapoor and E. Weisstein, ``Ten Problems in Experimental Mathematics," *MAA Monthly*, (**113**) June-July 2006, 481-509. [CoLab Preprint 270].

"The object of mathematical rigor is to sanction and legitimize the conquests of intuition, and there was never any other object for it."

- J. Hadamard quoted at length in E. Borel, *Lecons sur la theorie des fonctions*, 1928.