

Computing and Reality: Pursuing the Limit of Algorithms

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Birth of Computing: 1200 years ago!

Musa al-Khwarizmi: Pioneer of Computing in Bagdad, cultural place of Islamic golden age.



(780-850 AD)
9th Century



Hisab al-jabr w'al-muqabala

→ Treatise Hisab al-jabr w'al-muqabala on **Algebra** (←al-jabr)

Provide **methodologies** written in *plain sentences*:

→ **Algorithms** (←al-Khwarizmi latinization)

“**Computing**” discovered well before “**computers**”:



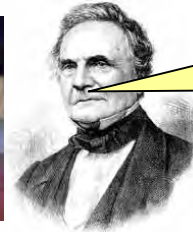
→ computers are *computing hardware*

Physical machines of a beautiful principle: **Computing**

Then came the computing machineries...

First computer!

*Analog special purpose
computer manually powered*



Manual handle
cranking automation
of Computing (1822)

Atanasoff-Berry Computer
1937



1947

Vector computers, 1960
CDC Star 100 (100 MFLOPS)
1972



Computing paradigm shifts:

Sequential computing

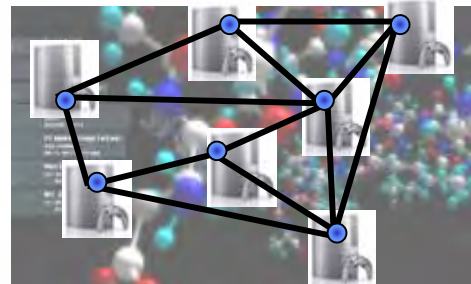


**Parallel computing
(SIMD/MIMD)**



**Distributed computing
(Network=Grid/P2P/etc.)**

Teraflops@Home
5th June 2007



Protein folding@home / P2P network

4 Pillars of Computing Science

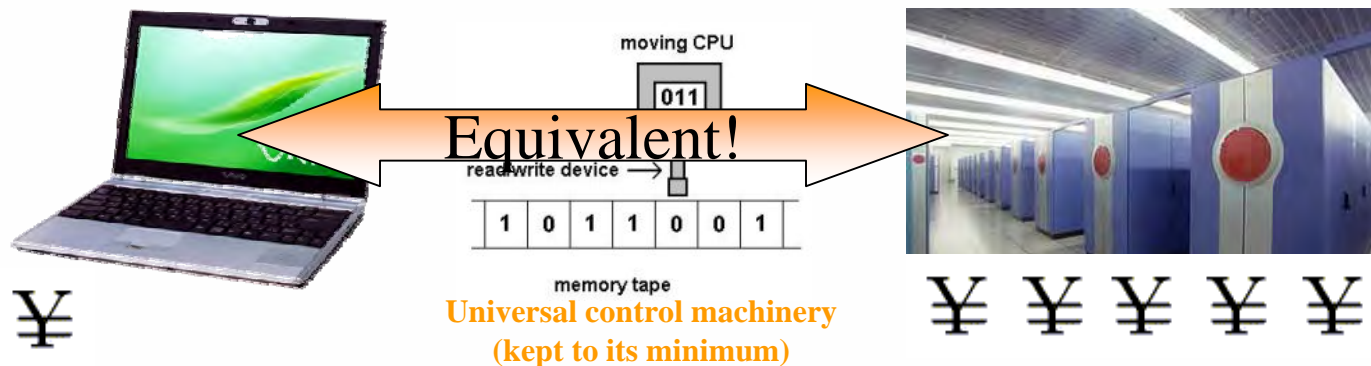


A. Turing

A. Church

① **Universal Turing machine:** (1936)

(=General purpose generic computers)



② **Duality:** data inputs / programs (computers can be emulated)

③ **Self-reference:** Recursion (Lamba calculus of Church, 1936)

④ **Tractability** P, NP, NP-hard, NP-complete, etc..

& Intractability: Cannot decide whether a program stops,
Cannot decide whether a program has a bug

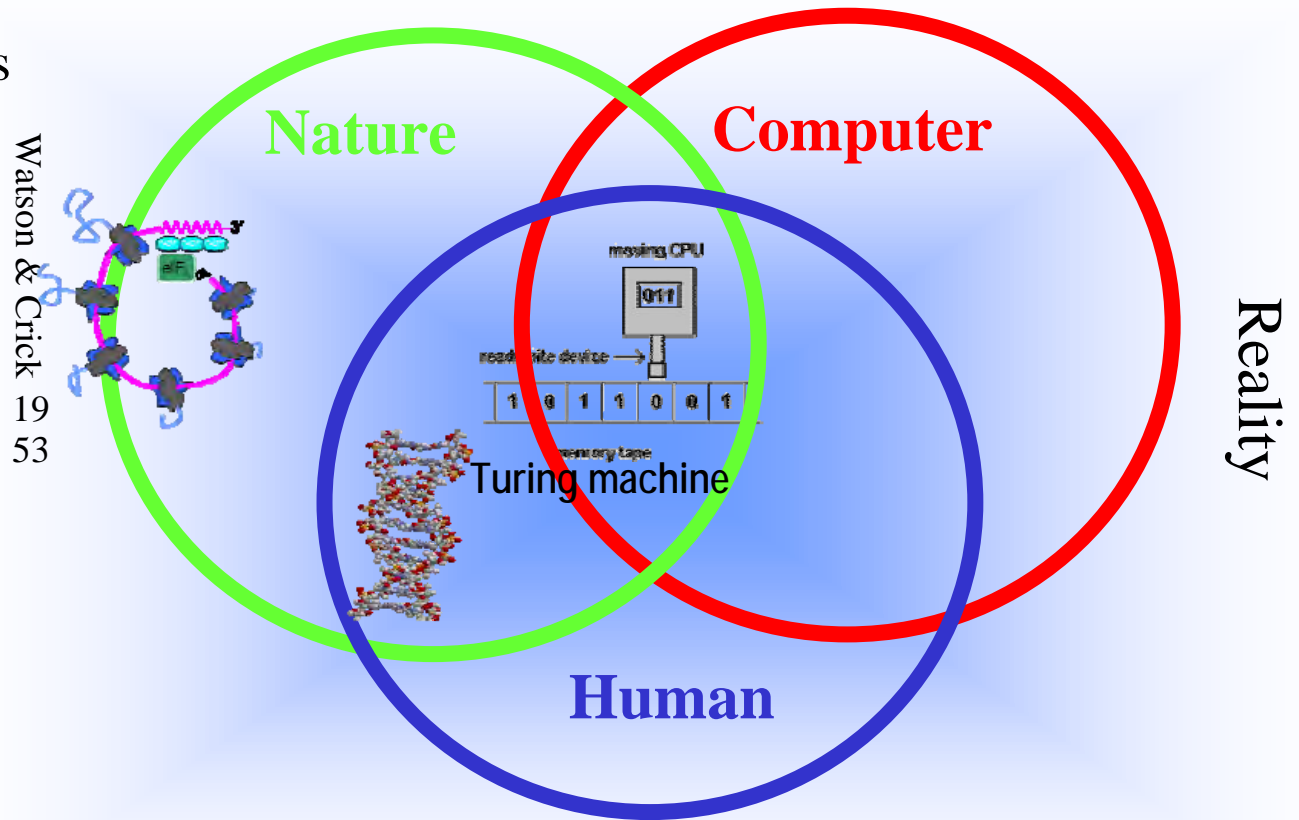
Computing Science & Reality: Algorithm

Quaternary DNA strings



Watson & Crick
1953

Self-reference of ACGT basis
Duality: GENE/PROTEIN

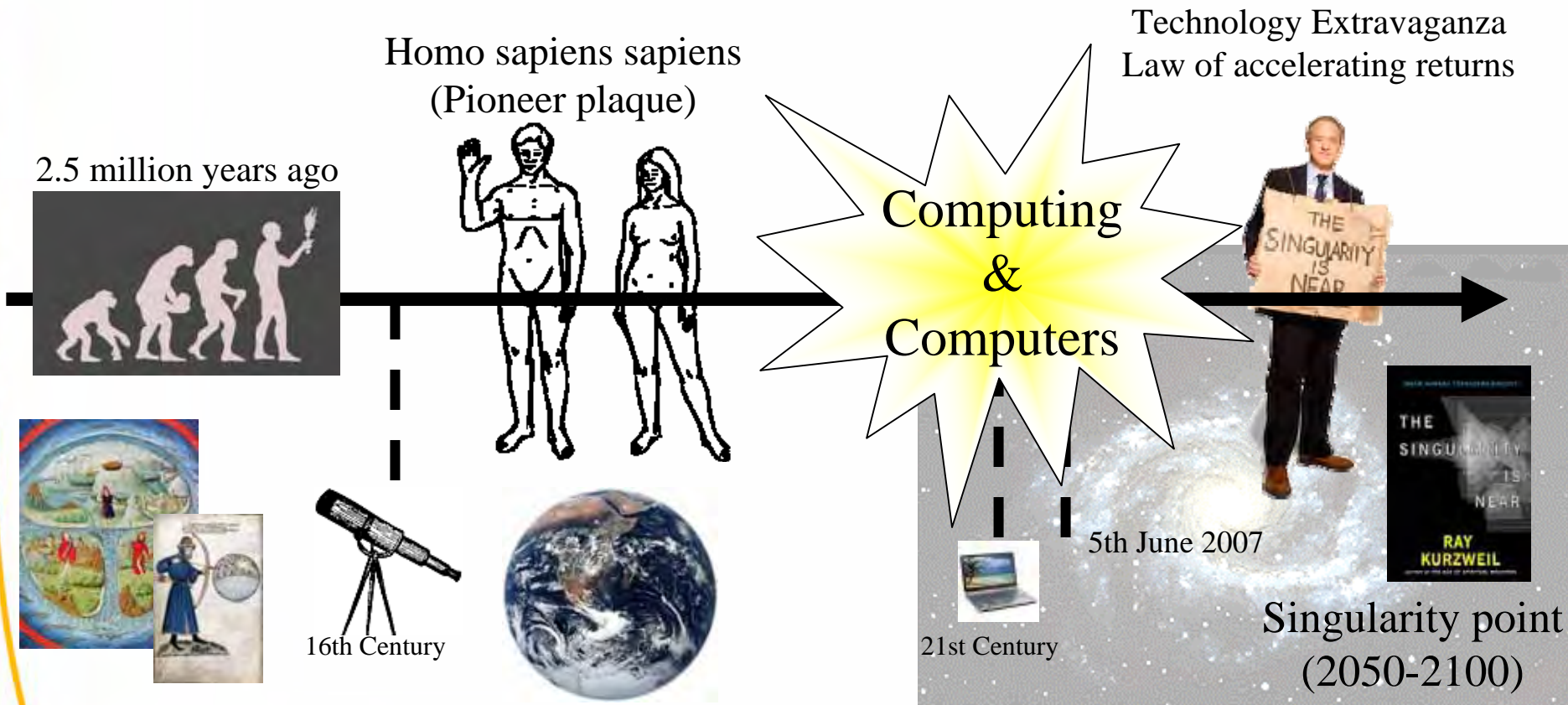


Algorithm = **Common language** of Nature ↔ Human ↔ Computer
= **Common principle** of Reality



Long term impact of Computing?

Computers: Human novel affordances



Computing changed **human thinking**, our perception of reality

Will computing affordance spur a new mankind specie ?
(Will Homo sapiens sapiens yields Homo cyberneticus?)

Computing: Anthropomorphic evolution?

Computing already allowed us to explore **new frontiers!**
Adventurous Human continue to spread on...



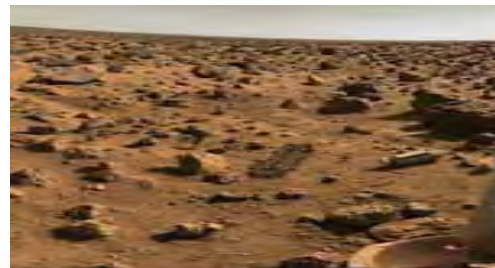
12 April 1961
Yuri Gagarin



20 July 1969
Neil Armstrong



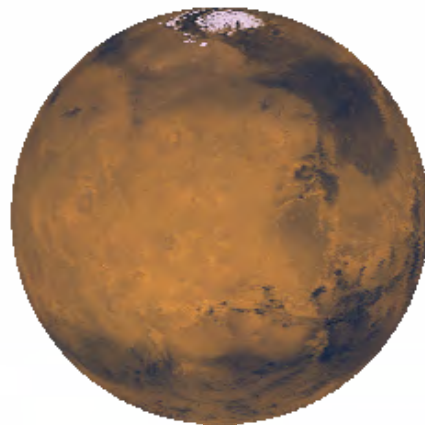
2 November 2000
International Space Station
(always inhabited since then)



Mars

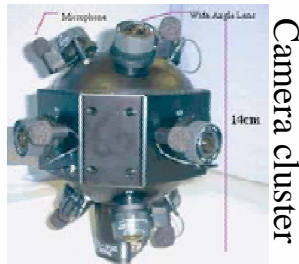
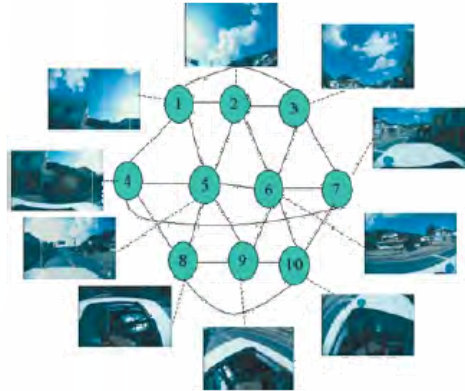


Today's interaction of Computing with Reality



Computing and Sensing: **Deeper collision**

Computational Photography



(full field of view video, no dead angle)

Super-sensorial information: 360 full view omnivideo
Powerful imagery in computer vision: **no intrinsic parameters**
(no calibration!)

Computing and Sensing:

Computational lens of reality



Clairvoyance (with Sony corp.)

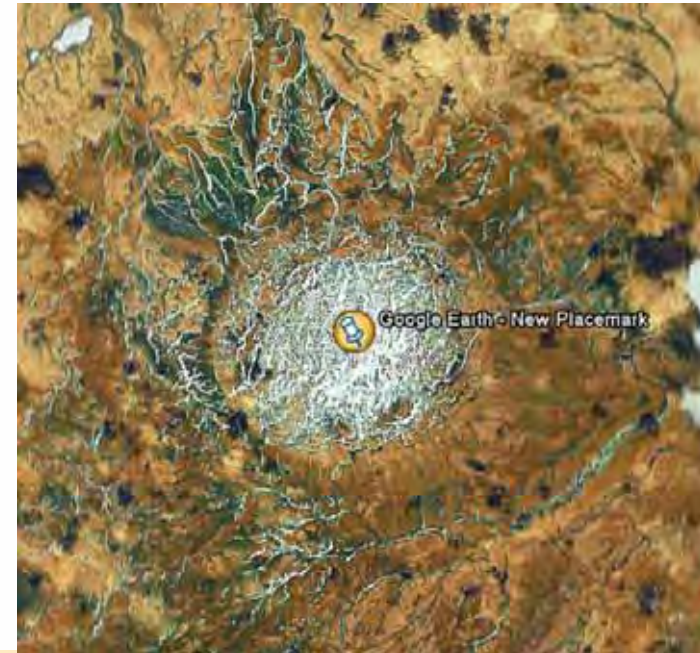
Capture first, discover later! Massive consumer data

Super-sensorial information

Extra-lucidity or extra-consciousness from that abundance?

Computing and Sensing: Reality lenses

...Data Mining...



Capture first, discover later!

New human discoveries using Google Earth (meteorite crater)



Automatic SETI search for extraterrestrial life

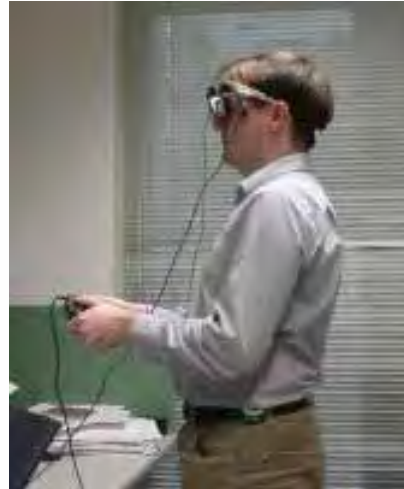


Computing and Sensing: Spammed reality?



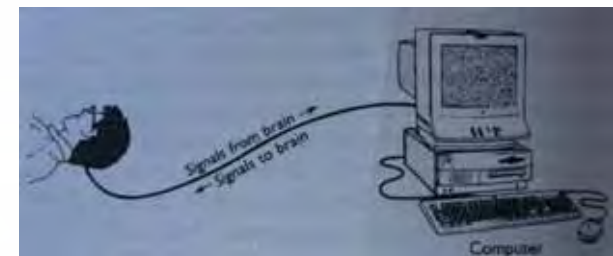
How can we **trust** (authenticate) our digital sensori information?
Is a digital picture **real**? (Anyway, was a film picture real?)
→ Digital forgery / Risk of **spammed reality**?

Computing and Virtual reality



Virtual Reality
=
(Realworld-like)
Image Generator

*Today, provide **external experiences** (sensorial) only.
Tomorrow, will provide **internal experiences** (emotions)?*



Computing & Virtual reality: 2007 **Society**

Massive VR communities. Novel **social/ethical** behaviors?



Second life



Sony Home on PS3 (Courtesy SCEI)

Avatar **criminality**, virtual/real **prison**?

Virtual Reality and Reality: Facets

Is VR *really* virtual?



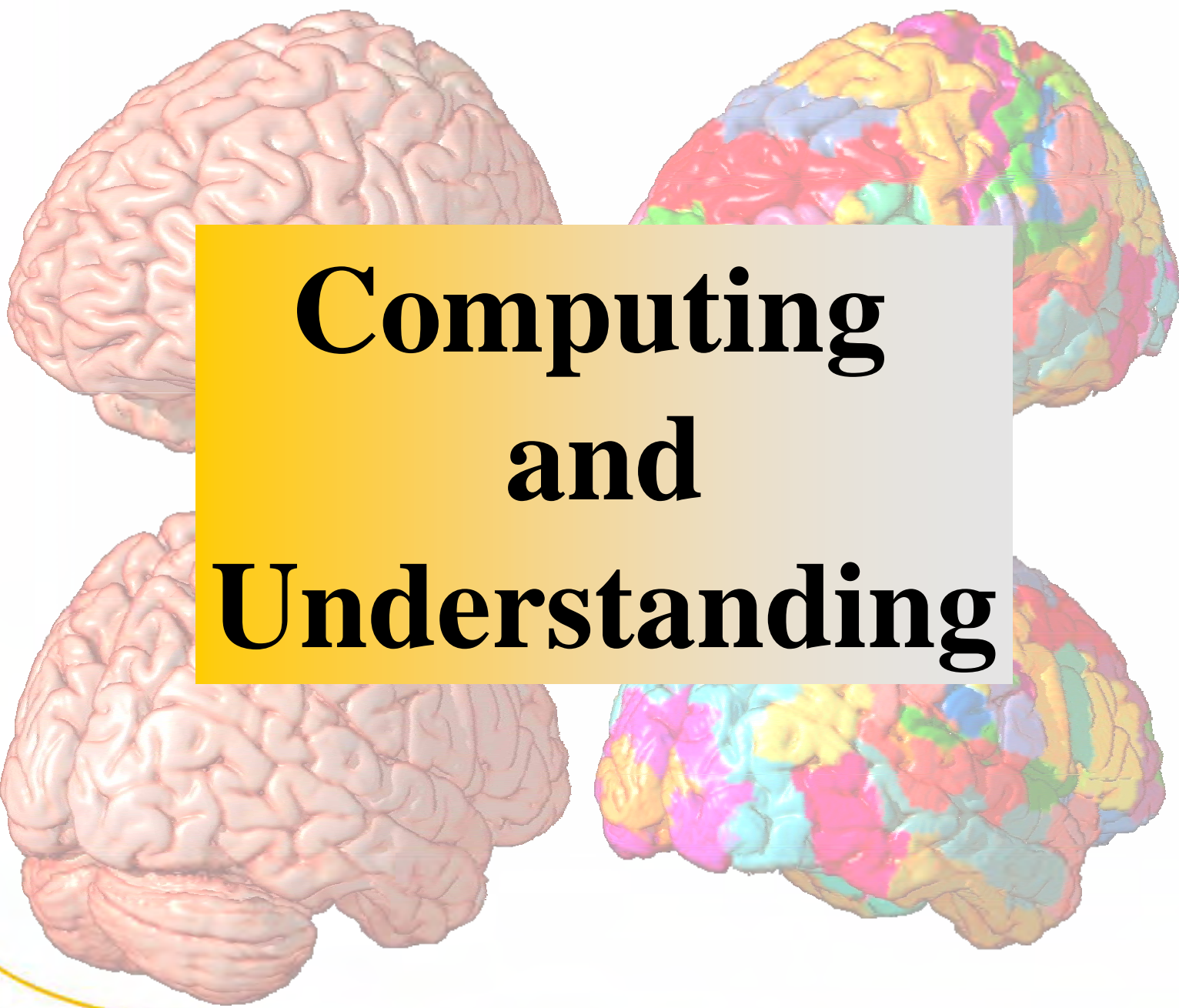
Flight simulator



Stewart platform



No, Virtual reality is **real**: it physically exists (cannot achieve zero gravity with a simulator)
→ Unbreakable laws of physics (postulate?)
→ VRs are computed **faceted realities**.

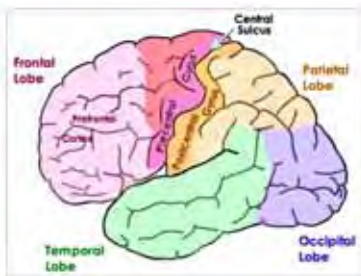
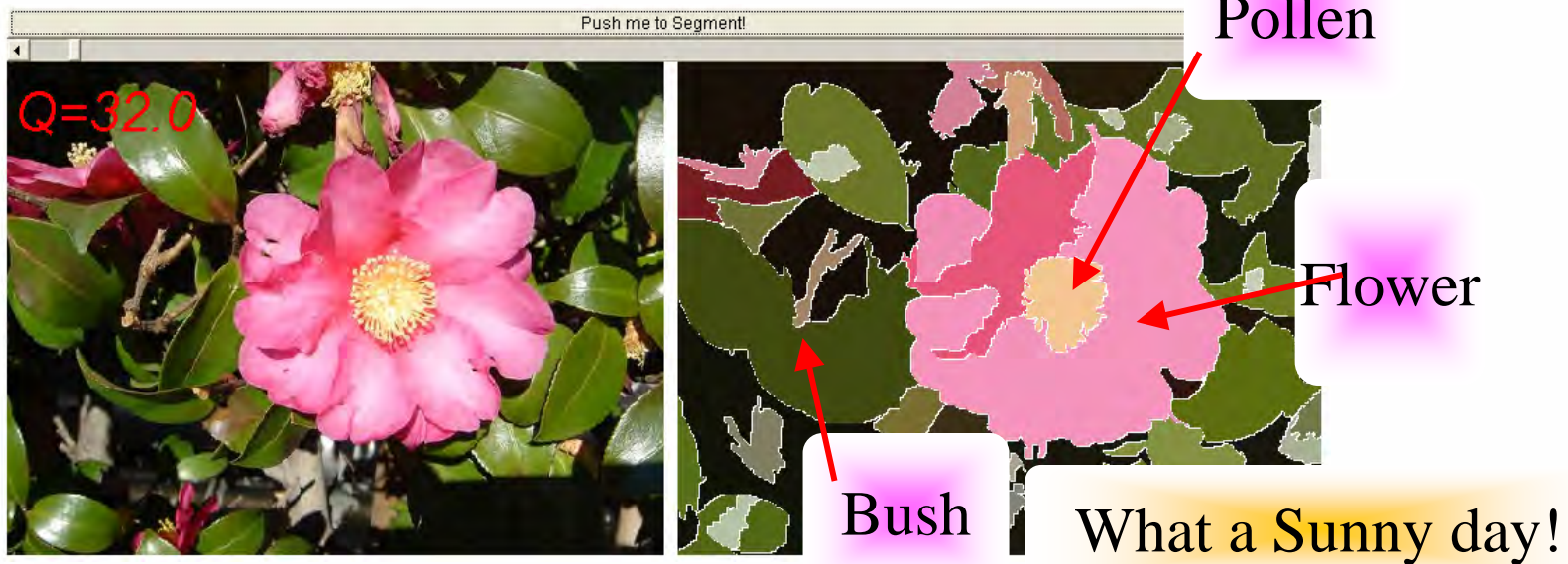
The image features four 3D models of a human brain arranged in a 2x2 grid. The top-left and bottom-left models are rendered in a realistic, light pinkish-tan color, showing the intricate folds and grooves of the cerebral cortex. The top-right and bottom-right models are color-coded, with different regions of the brain highlighted in various colors such as red, yellow, green, blue, and cyan, likely representing functional areas or specific neural pathways. A central text box is overlaid on the middle of the grid.

Computing and Understanding

Computing \neq Understanding

Image segmentation (\neq image understanding)

(from million of pixels to hundreds of areas)



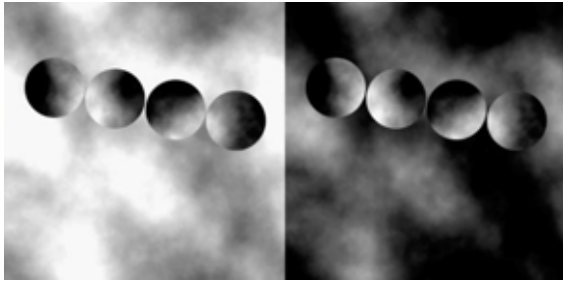
Visual pathways: perform both at the *same time*
segmentation and **recognition: dynamic system**

Statistical Region Merging,
IEEE Transactions on Pattern Matching and Intelligence, 2004

Image segmentation: An ill-posed problem?

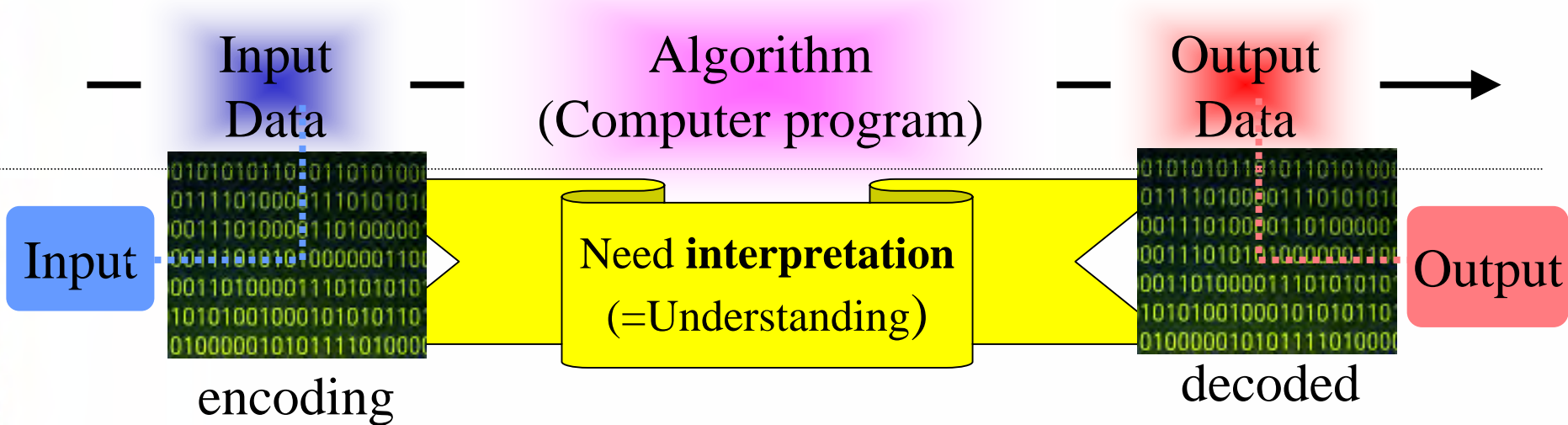


Do we understand ourselves what is segmentation ?



Many perceptual phenomena, difficult to model the task solved by the Brain!

Why Computing is not Understanding?



Input needs to be **encoded**, output to be **decoded**

Interpretations of encodings yield output understandings/**dualities**

(eg. Homogeneous vectors and duality point/line in projective geometry)

→ **Elegance, beauty** of solutions...

Computing \neq Understanding: Probabilistic Checkable Proofs (PCP):

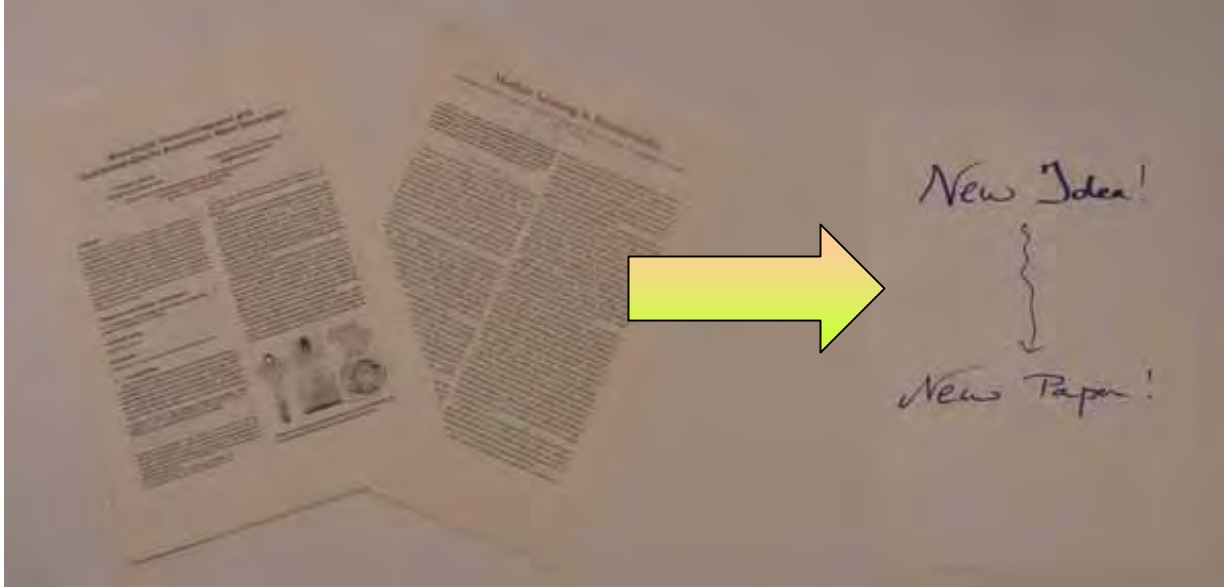
Computers can check with high probability digital proofs by inspecting **only 3 bits**.

Yet they do not understand! We do.

B. Chazelle, Proof at the roll of the dice, Nature 2006.

Computing and Science: Epistemology & Creativity

Limits of Computing: Our Creativity?

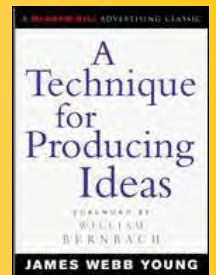


Recipe

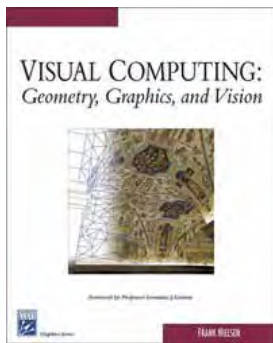
- Gather material
- Digest them
- Do something else
- **Ah ha! happens**
- Test the idea



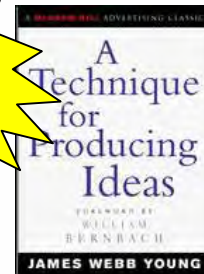
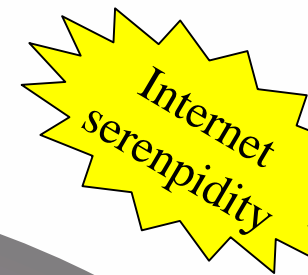
Framework for thought, foundations for sparkling ideas
A Technique for Producing Ideas
By James Webb Young (48 pages)



→ **Breaking silos!!!**



Visual computing, 2005, ISBN 1584504277



Creativity

Information Theory
of the Visuals

3D Cinematography

Computational Photography

Image Processing

Visual Intelligence

Computer Vision

VISUAL COMPUTING

Information
Technology

Computer Graphics

Machine Learning

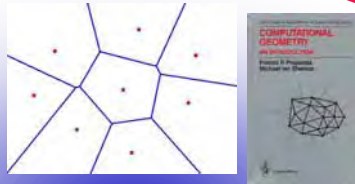
Computational Geometry

Abstraction

Creativity by Abstraction (Reductionism)

Computational Information Geometry

Computational information geometry

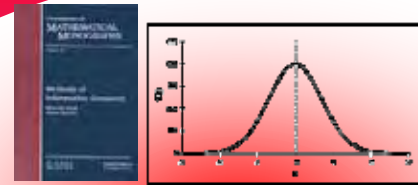


Computational geometry

Discrete/Combinatorial
geometric algorithms



Preparata



Information geometry

Points=Information
Riemannian geometry



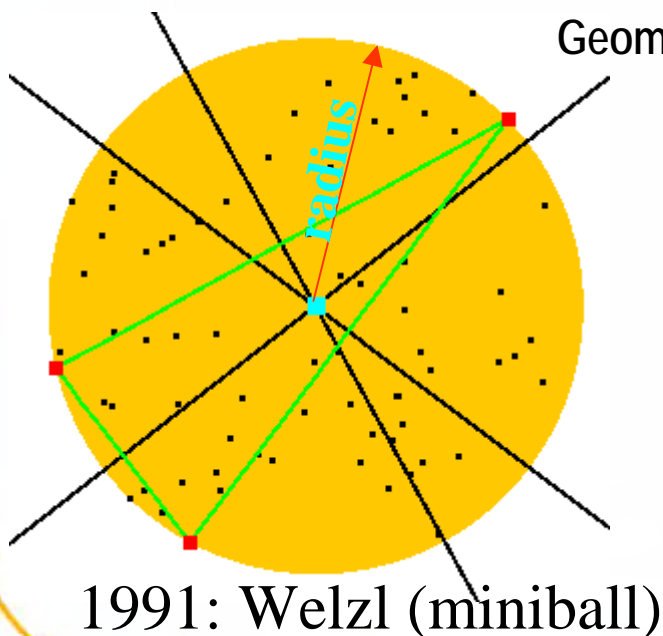
Amari

Abstraction: Powerful principle yielding deeper understandings

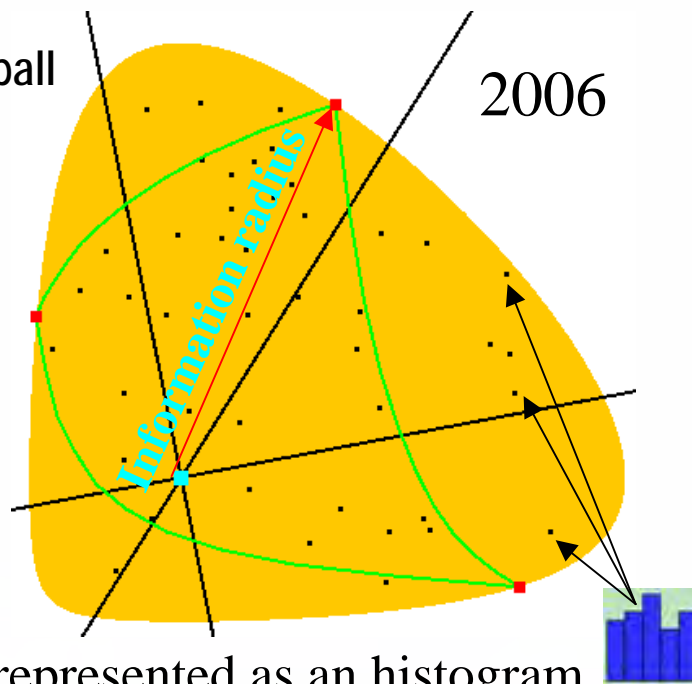
Computational Information Geometry

Example: **1-clustering**=summarize data to a **single point** (MinMax)
Compute the **information radius** (spread)

Data are geometric points
(=Euclidean points)

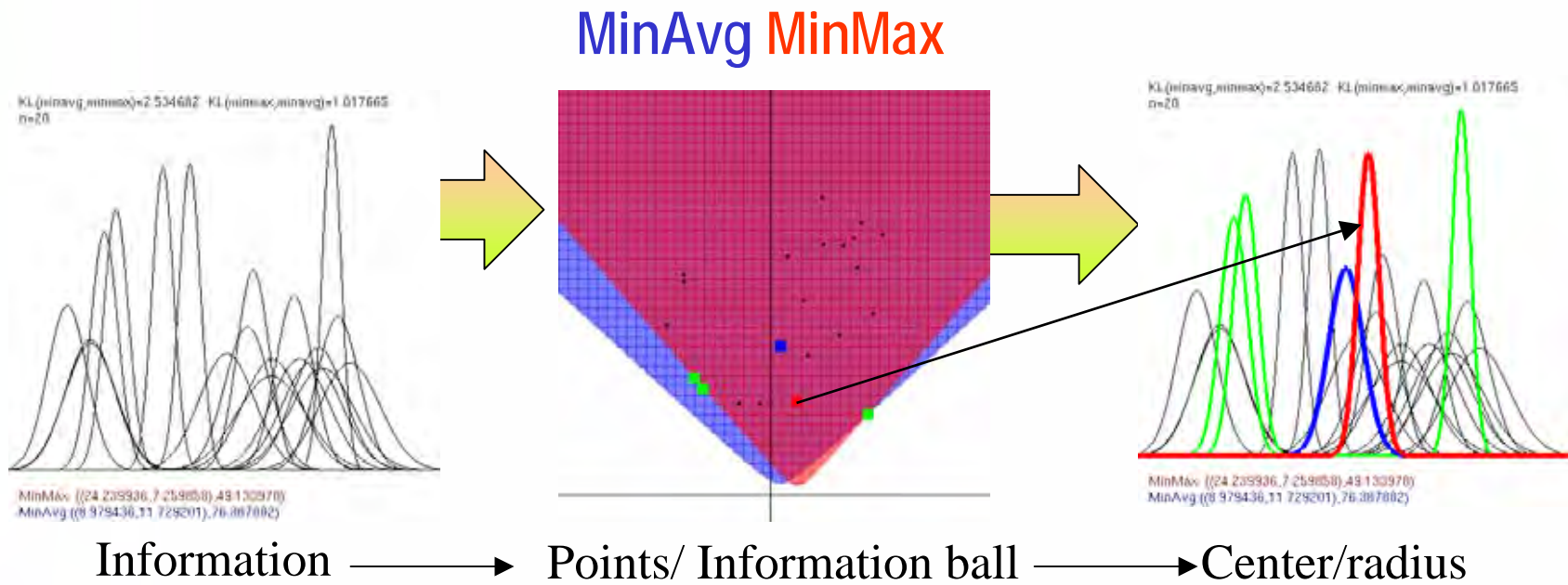
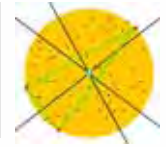


Data are information points
(=abstract geometric points)



Each image is represented as an histogram
Use **relative entropy** as a **distance**
(as known as Kullback-Leibler divergence)

Example: Statistical Information Ball



Open House
Demos
June 7/8

Many applications of INFOBALL:

- Universal source coding
- Statistical decision theory
- Text-to-Speech synthesis
- Etc.

A point of view

- Computer = Computing machinery
- Computing \neq Understanding
- Computing & Creativity?
- Computing & Civilization?

Short term prediction:

20th Century: Science of formula

21st Century: Science of algorithms

2007's Al-Khwarizmi challenge: Quantum computer
DNA computer
Exotic computer