

Universities in the Information Age

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Abstract

Universities need to think about new academic structures for computing and information science and implement the best ideas.

- Cornell is trying something new.
- I will describe it and explain it's rationale.
- Intel played a role which I will describe.

Outline

- What is the problem that requires new structures?
- What is Cornell doing?
- What is a rationale for action?
- Conclusion

Outline

- What is the problem that requires new structures?
 - What is the opportunity in CIS?
- What is Cornell doing?
 - Similar plans are emerging elsewhere.
- What is a rationale for action?
 - A look behind the Information Revolution.
- Conclusion

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What is the problem?

- “looming national crisis” identified in 1999 Chronicle of Higher Ed.
- CS Dept. enrollments are high and climbing
- demand for collaborations and advice is high
- society’s need for university research is large

Computer science as a discipline is not widely understood nor appreciated even within the academy, making judgments about it difficult and consensus rare and narrow.

In particular, few people see the underlying issues and opportunities clearly. These problems are **symptoms**.

What is the problem?

- “looming national crisis” identified in 1999 Chronicle of Higher Ed.

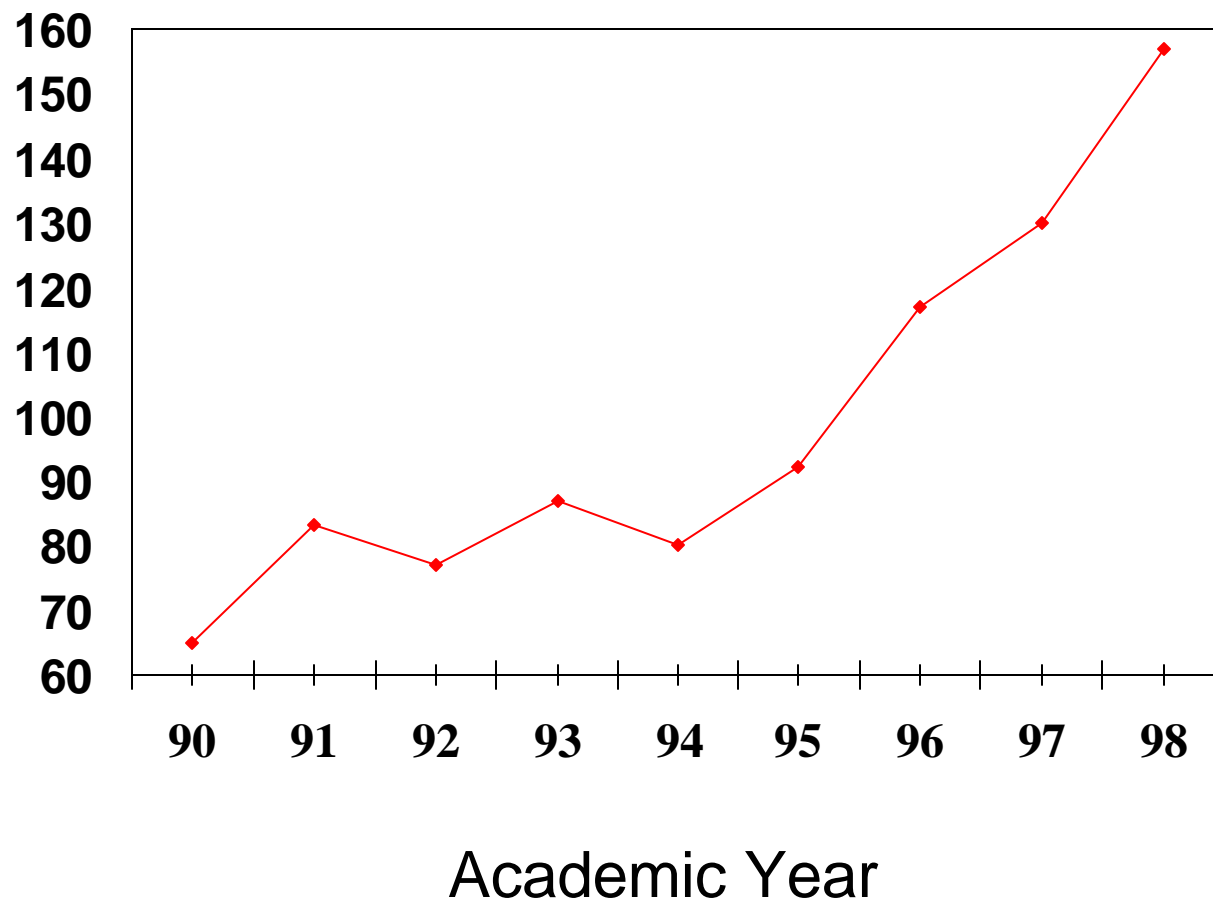
competition for talent is fierce.

- 500K IT job openings
- all faculty can easily move (to green pastures)
- potential faculty and grad students have excellent alternatives.

What is the problem?

- CS enrollments are high and climbing (see graph)
 - high faculty work loads
(teaching, advising, staying current, managing, students taught, prog courses expand)
 - TA shortages fewer grad students, more research funds

Graduating Seniors in CS at Cornell



What is the problem?

- demand for collaborations and advice is high both inside and outside universities.
 - NSF, KDI, ITR requirements
 - DARPA identifies **critical** problems
 - corporations want help
 - time spent on proposals exceeds returns

What is the problem?

society's need for university research is large

- many hard problems
 - reliability and security
 - networks
 - bioinformatics
 - telemedicine
 - "nanoinfotech"

- long term solutions are needed
 - industry has limited horizon
 - industry has limited environment

What is the problem?

Computer science is not well understood, so planning for it is contentious.

- CS is not really a science or an academic field (1997 Task Force faced this view).
- Can just use more NA people to teach computing (58 engineers at Cornell think they “do CS”).
- It’s just the technology and programmers that we need. Every field will do its own computing, just as Physics always had.

Outline

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- ↳ ■ What is Cornell doing?

- What is a rationale for action?

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How did Cornell respond?

- 1997 Research Futures Task Force in Science
- 1997 Digital Futures Committee
- 1999 Computing and Information Science Task Force

How did Cornell respond?

- 1997 Research Futures Task Force in Science
 - Broad and large university committee
- 1997 Digital Futures Committee
 - Eng focus, CS and EE thrust
- 1999 Computing and Information Science Task Force
 - Broad university committee

CIS University Task Force Report*

*“We believe that Cornell should create a **central home** for computing and information research and education, **spanning the entire campus.**”*

- new courses
- new concentrations
- new majors
- enabling new research **university wide**
- possibly new units

* www.cs.cornell.edu Quick Links

CIS Task Force Report

recommends a **new** kind of academic home - a **faculty**.

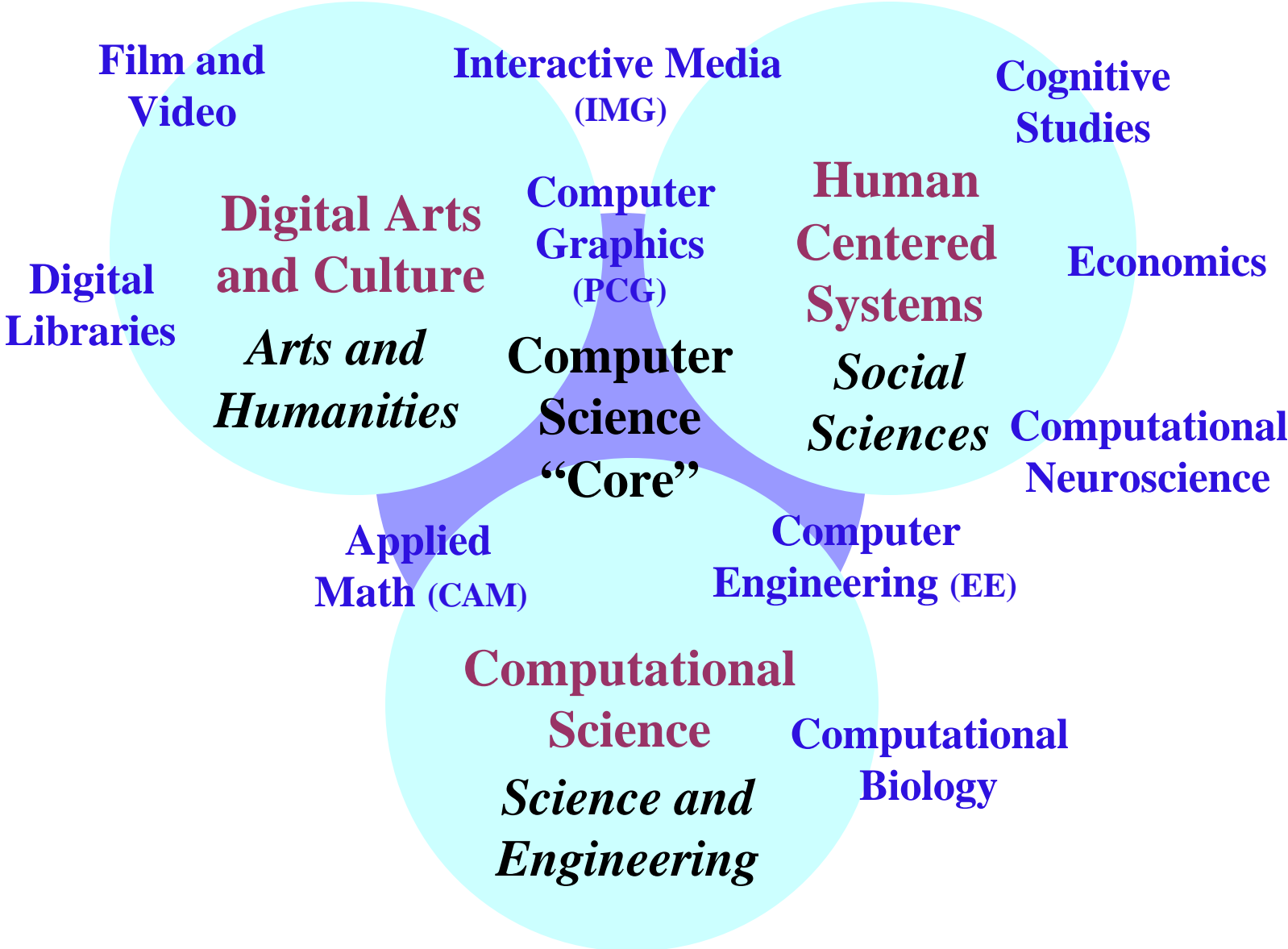
which is **NOT**:

1. Single large dept
Eng
Arts
Univ-level
2. Center or Laboratory
3. Division
4. College (CMU, Georgia Tech, ...)

Attributes of a Faculty

- undergraduate teaching role with majors in **several colleges** (CAS, Eng, CALS ...).
- minors and concentrations in focal areas, across colleges.
- undergraduate computing program, like Knight Writing Program.
- regular faculty, CS and beyond
- faculty in common with other units, “members of the FCI”
- independent budget managed by dean-level person.
- fund raising functions.

Bringing Ideas from Computing and Information Sciences to Bear on Disciplines Across Cornell



Opposing Views

- it is **Information Technology** that is pervasive and critical, not Information Science (which is not even a real subject).
- CS is not a real science and it has a service mission like mathematics that makes it appear more important than it is.
- Physics is the right model, CS will be the “new physics”, have a small dept. with many applied units, labs, centers, depts.
- other subjects are more important, e.g. the environment, astronomy, biology, materials.
- “eegad they are right”, CS will take over everything, we must stop them.

University Faculty Senate Views

- CIS Task Force is mainly right, must go forward
- create office of CIS to figure out details (but consult Senate)
- go slowly, don't let CS have all the money

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- Ⓓ ■ What is a rationale for action?

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Cornell has recognized **Computing & Information Science**

Task force on Strategic Research Initiatives recognized three areas as enabling -

- Information Sciences
- Genomics
- Advanced Materials

Information science is critical to the other two. Actions taken in **Genomics, Advanced Materials**. CIS Task Force is operating to plan action for **Information Sciences**.

Rationale - the key judgement

Computing and information science is now relevant to every academic discipline at Cornell.

CS Vision statement from 1995 reflects this:

“In the great American universities of the 21st century it must be possible for any student to bring to bear on any subject the ideas and technology of computer science.”

Evidence

What is the evidence for this judgement?

relevance “game”

Information Revolution

NSF role

CISE programs

KDJ

ITR

Intel role

- Technology for Education 2000 Projects
- Role of CSD in T4E

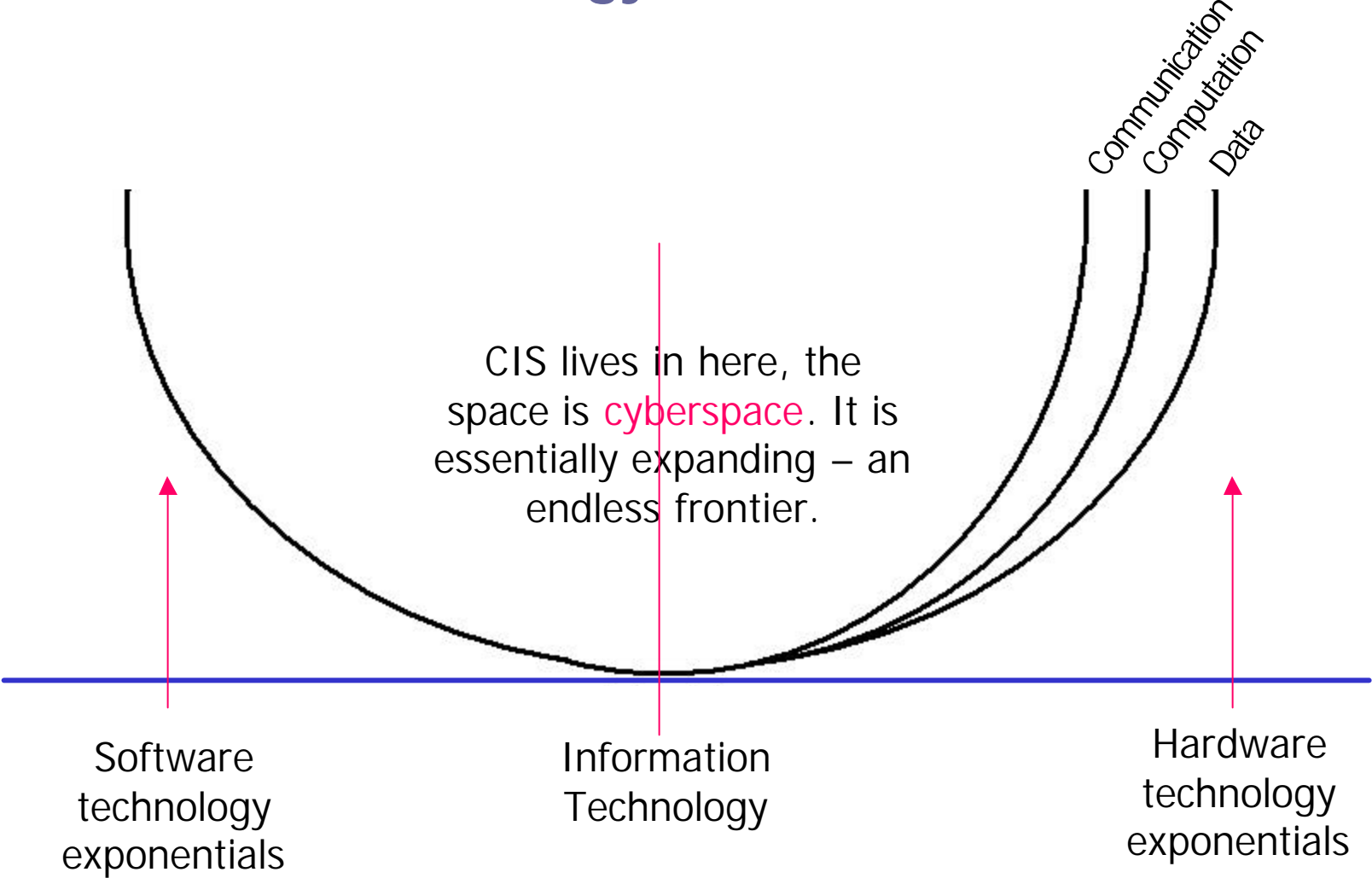
The Projects

- Computer Science
 - Quality of Service
 - Scalable, Secure Computing
 - Structured Access to Information
 - Computational Clusters
- Engineering
 - EE – Semiconductor-Processing CAD & 3D MEMS Simulation
 - Mechanical Applications
- ChemE Simulations
- Algorithms for Engineering Simulations
- Operations Research
- Environmental Computing
- Computer Graphics & Digital Libraries
- Physical Science
 - Materials Science
 - Solving Quantum Chromodynamics

The Projects – Continued

- Training Physics PhDs
- Instructional Physics Simulations
- Condensed-matter Physics
- Computational Chemistry
- Mathematical Computing Environment
- Biotechnology
 - Computational Biology
 - Bioinformatics
- Biometrics
- Biomedical and Food Process Engineering
- Predicting Effects of Technological and Regulatory Change
- Business and Arts
 - Parker Center for Investment Research
 - Digital Arts
 - Architectural Design

Relation to Technology



The Information Revolution

- obvious manifestations

The new economy

- Information corporations: Microsoft, Oracle, ...
- Information service industry: Amazon.com, theGlobe.com
- 1/3 of US economic growth since 1992
- 7.4 million Americans at wages 60% above average
- E-commerce is booming (expect \$1.3 Trillion by 2003): CISCO, Compaq

The Information Revolution - obvious manifestations

New world

- **Explosion** of information on the Web: 5M domain names, .5M servers, 30M computers connected, a million new pages per day!
- We are **connected** - live in cyberspace
- We are **not alone** - “digital companions”
- The Deep Blue **machine** is world chess champion

Scientific Basis - CIS is the intellectual core

- **The Internet**
 - Packet communications
 - Protocols (TCP/IP)
- **Web/Mobile code**
 - Java programming language
 - High-level PL's research
- **Cryptography**
 - Computational complexity theory
 - Intractable problems
- **E-business**
 - Security
 - Cryptography

- **Multimedia**

- Data compression algorithms
 - Computational geometry

- **Search engines**

- Vector space model
 - Computational graph theory
 - Natural language technology

- **Computational Science**

- Parallel compilation
 - Cluster computing
 - Theory Center role

- **Cognitive Science**

- Computational theory of mind
 - Intelligent systems
 - Robots

Comparison to the **Industrial** Revolution

- Science and technology create new sources of wealth- in waves
- Driven by **physical sciences**
(steam, electricity, atomic energy, advanced materials)
- New educational institutions - military engineering, civil engineering, led to engineering colleges
- Massive social change - automobile vs. computer

Scientific Revolution

- From moving atoms to moving bits
(books, tapes, CD's, movies, models)
- Founded on **laws of computation and information**
- the theory
- Ideas are **realized** in software – experiments
- There has been a paradigm shift, a new “system of thought”

Fundamental abstractions of CIS

digital abstraction

Von Neuman machine

universal (Turing) machine

symbolic computing / automatic translation

theory of algorithms / data / complexity

process / transaction abstraction

The computational theory of mind

AI and Cognitive Science have created a new theory of mind

- major awakening of imagination (Pinker quote¹)
- general definition of mind (Pinker quote²)
- predictive power in psychology
- mentalistic language of CIS

Steven Pinker, How the Mind Works

Quote

“For I believe that the discovery by cognitive science and artificial intelligence of the **technical challenges overcome by our mundane mental activity** is one of the great revelations of science, an awakening of the imagination comparable to learning that the universe is made up of billions of galaxies or that a drop of pond water teems with microscopic life.”

- Steven Pinker, How the Mind Works, p.4

Steven Pinker, How the Mind Works

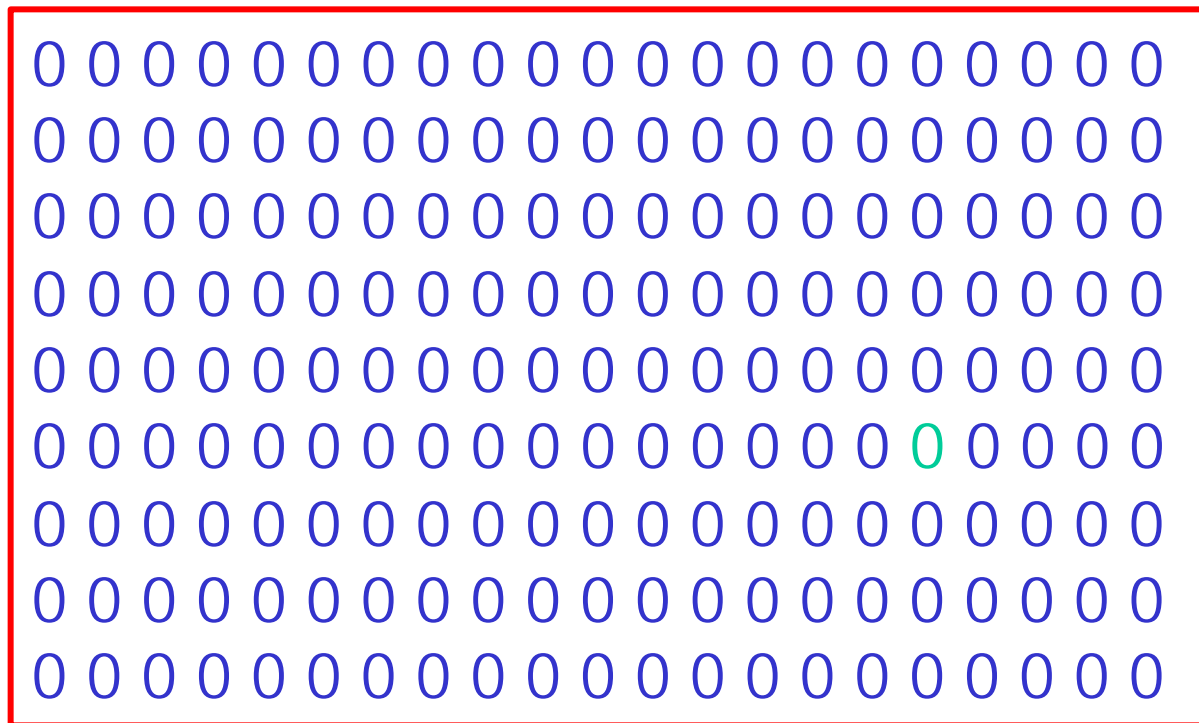
Quote

“The mind is a system of organs of computation, designed by natural selection to solve the kinds of problems our ancestors faced in their foraging way of life, in particular, understanding and outmaneuvering objects, animals, plants, and other people.”

- Steven Pinker, How the Mind Works, p.21

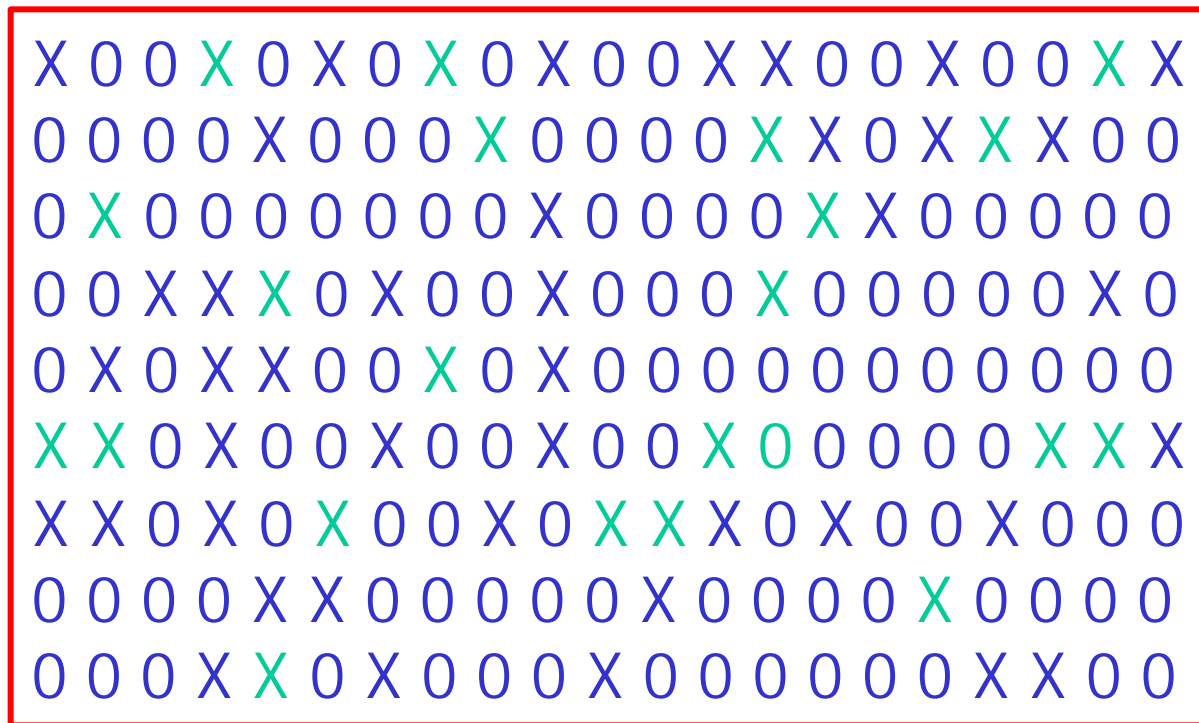
Ann Treisman visual experiments

Green 0 in sea of blue.



Ann Treisman visual experiments

Green and 0.



Ann Treisman visual experiments

predict

- focusing on one location causes peripheral features to float unattached – color and shape
- same with letters in words in peripheral vision as in “the World’s Worlds Coffee”

How many F's

Finished files are the result of years of scientific study combined with the experience of years.

Fly to London Virgin

Talking about computer systems

Why isn't my computer printing? Because the OS does not **know** that you replaced your dot-matrix printer with a laser printer; it still **thinks** it's talking to a dot-matrix printer and is waiting for an acknowledgement from the printer.

But the printer is **ignoring** the message; it does not **understand** it, because it expects it to begin with a %.

You need to get the **attention** of the OS.

Nuprl as an intelligent agent

It's successes embolden us to talk about "how Nuprl thinks."

Example 1.

My gosh, it **realized** that $\exists x:A.B$ was decidable and performed a case analysis, how did it **know** that?

Nuprl as an intelligent agent

Example 2.

Did Nuprl prove all the other subgoals? No, it doesn't **believe** that E is an equivalence relation, so it asked a lot of questions I didn't expect.

What is it asking about? It wants to **know** why certain values are in range? What values? Only those that change the security level.

It should **know** that, the value is in range. That is a requirement of the decryption function. That's part of the contract for that process.

Nuprl as an intelligent agent (cont ...)

Example 2. (cont ...)

Yes, but Nuprl **claims** that the argument to the decryption function is not of the right type. But that can't be, ask it to **explain** why it is not of the right type.

It **reports** that if process Q sent its message M with the decrypt argument just before monitor M failed, then Q could have used an undetected modular equivalence to generate the message value.

Well I'll be darned. We all missed that.

Conclusion

- CIS is emerging as one of the major intellectual disciplines of the next century. Its scope in university terms will be at the **scale of colleges** not departments or centers.
- CIS as a body of knowledge occurs early in the **"tree of knowledge"** with consequences for nearly all other subjects and disciplines.

Conclusion (cont ...)

- CIS has the character of science, quantitative mathematical, predictive; the character of technology, practical, constructive, with an engineering component and the character of art, shaped by elegance and beauty and loosely constrained by laws limited largely by imagination.
- CIS is a bridge between the humanities and arts and the sciences as we see most clearly in the computational theory of mind.