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INFORMATION TECHNOLOGY AND ITS IMPACT ON SCIENCE CULTURE AND SOCIETY

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INFORMATION TECHNOLOGY AND ITS IMPACT ON SCIENCE, CULTURE AND SOCIETY

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PREAMBLE

We are in the midst of what is popularly called the information revolution—a revolution which was born shortly after the end of World War II.

As a student at MIT and later as an instructor at Columbia University, I witnessed the birth of this revolution and observed at close distance its progression and impact

My lecture is a brief account of my perceptions of the birth and evolution of information technology and its impact on science, culture and society

ORGANIZATION

Part A

Evolution of information technology (IT) and intelligent systems technology (IST)

From sciences of the natural to sciences of the artificial

From human IQ to machine IQ (MIQ)

Impact of IT/IST on science, culture and society

Part B

Organization of information-technology-centered research and education

PART A

THE BEGINNING OF THE AGE OF INFORMATION AND CONTROL

Three major events (ca.1946)heralded the beginning of the age of information and control

Invention of the transistor
Debut of cybernetics (Wiener)
Debut of information theory (Shannon)

I heard the first presentation by Shannon of his work at a meeting in New York, in 1946, and was deeply fascinated by his ideas. His lecture opened a new world

THE NEW WORLD

The new world was the world of machine intelligence and automated reasoning

It was widely believed that there were no limits to what machines could do

The era of thinking machines has arrived

Inspired by what I saw, heard and read, I wrote an article about thinking machines which was published in a student magazine

THINKING MACHINES—A NEW FIELD IN ELECTRICAL ENGINEERING

Lotfi A. Zadeh

"Psychologists Report Memory is Electrical," "Electric Brain Able to Translate Foreign Languages is Being Built," Electronic Brain Does Research," "Scientists Confer on Electronic Brain,"—these are some of the headlines that were carried in newspapers throughout the nation during the past year. What is behind these headlines? How will "electronic brains" or "thinking machines" affect our way of living? What is the role played by electrical engineers in the design of these devices? These are some of the questions that we shall try to answer in this article.

Through their association with mathematicians, electrical engineers working on thinking machines have become familiar with such hitherto remote subjects as Boolean algebra, multivalued logic, and so forth. And it seems that the time is not far distant when taking a course in mathematical logic will be just as essential to a graduate student in electrical engineering as taking a course in complex variable is at the present time. Time marches on.

A GLIMPSE INTO THE FUTURE (LAZ 1950)

It is 1965. Three years ago for reasons of economy and efficiency the trustees of Columbia University have decided to disband the Office of University Admissions and to install in its place a thinking machine to be called the Electronic Director of Admissions.

Installation was completed in the spring of 1964, and since then the Director has been functioning perfectly and has won unanimous acclaim from administration, faculty and student body alike

Columbia Engineering Quarterly, January 1950

ELECTRONIC DIRECTOR OF ADMISSIONS (1950)

probabilistic if-then rules

record $\xrightarrow{\text{encoding}}$ $(a_1, \ldots, a_n)$

accept if Prob $\{Event\ (a_1, \ldots, a_n)\} \geq \alpha$

and Condition D

Event: *survive first year*

Condition: registration $\leq N$

If X is A and Prob (Y is B|X is A) is C and

Condition is D then Action is E

EXAGGERATED EXPECTATIONS

Like others, I had exaggerated expectations. Here are two of many examples

On the occasion of inauguration of IBM's Mark 1 relay computer in 1948, Howard Aiken, Director of Harvard's Computation Laboratory, had this to say:

> *There is no problem in applied mathematics that this computer cannot solve*

In 1953, Burroghs Corporation started a project to design, manufacture and market a phonetic typewriter

BRILLIANT SUCCESSES AND CONSPICUOUS FAILURES

successes

landing men on the moon

GPS systems

search engines

bioinformatics

failures

summarization

simultaneous translation

automation of driving in city traffic

tennis-playing robot

EXAGGERATED EXPECTATIONS AND REALITY

Exaggerated claims and expectations persisted through the fifties, sixties, seventies and eighties

The difficulties of achieving AI's goals were greatly underestimated

But today it is not an exaggeration to say that we are in the initial stages of two related revolutions: information revolution; and intelligent systems revolution

Information revolution has higher visibility because it manifests itself in new products, while intelligent systems revolution is associated with enhancement of intelligence of existing products

INFORMATION SYSTEMS / INTELLIGENT SYSTEMS

INFORMATION REVOLUTION

INTELLIGENT SYSTEMS REVOLUTION

INTERNET
WORLD WIDE WEB
WIRELESS TELEPHONY
FAX
DIGITAL LIBRARIES
DATA MINING
INFORMATION RETRIEVAL
....

SMART CAMERAS
SMART APPLIANCES
SMART CARS
SMART ELEVATORS
SMART ROBOTS
INTELLIGEN MANUFACTURING
EXPERT SYSTEMS
SMART SEARCH ENGINES
SMART QUALITY CONTROL
...

Measure of intelligence: MIQ (Machine Intelligence Quotient)

IQ vs. MIQ (LAZ 1993)

MIQ= Machine Intelligence Quotient (Machine IQ)

- *IQ is a measure of human intelligence*
  MIQ is a measure of machine intelligence

- *IQ is class-independent*
  MIQ is class-dependent

  (MIQ of cameras and MIQ of washing machines involve different dimensions and different tests)

- *IQ is time-independent*
  MIQ is time-dependent
  (dimensions and tests change with time)

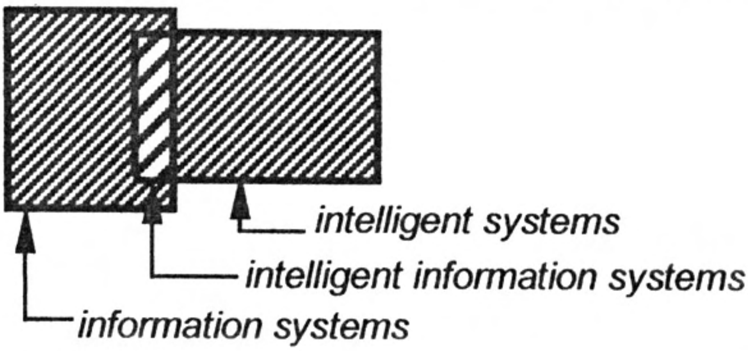
- *a human is intelligent if he/she has high IQ*
  a machine is intelligent if it has high MIQ

MACHINE INTELLIGENT QUOTIENT (MIQ)

Dimension of MIQ

- *handwriting recognition*
- *speech recognition*
- *natural language understanding*
- *summarization*
- *disambiguation*
- *image understanding and pattern recognition*
- *diagnostics*
- *unstructured storage and retrieval of information*
- *execution of high level instructions (expressed in NL)*
- *learning*
- *reasoning*
- *planning*
- *problem solving*
- *decision making*

INFORMATION /INTELLIGENT SYSTEMS (I/IS)



Information/intelligent systems = information systems + intelligent systems + intelligent/information systems

- *information/intelligent systems are emerging as the primary component of the infrastructure of modern societies*
- *conception, design, construction and utilization of information/intelligent systems constitute the core of modern science and technology*

ULTIMATE GOAL

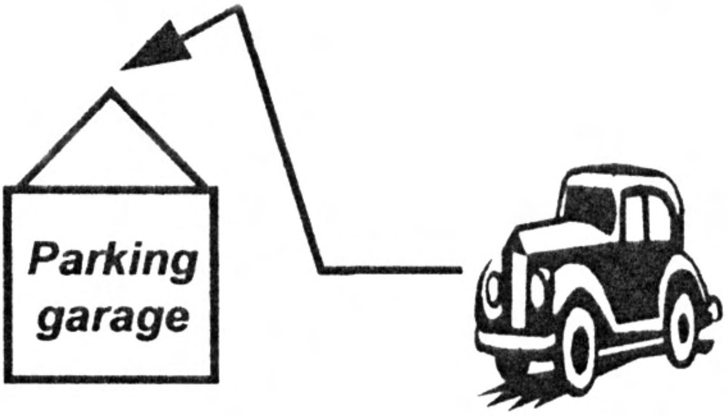
Intelligent Decision Systems

SUBGOAL

Intelligent Information Systems

INFORMATION SYSTEM vs. INTELLIGENT INFORMATION SYSTEM

SIEMENS FUZZY PARKING CONTROL (1996)



Parking Garage Marienplatz	***FULL***
Parking Garage Stachus	***FREE***

INFORMATION/INTELLIGENT SYSTEMS (I/IST)

Information/intelligent systems are becoming a reality

But why did it take so long?

The necessary technologies and methodologies were not in place

Key technologies: advanced computer hardware and software

advanced sensor hardware and software

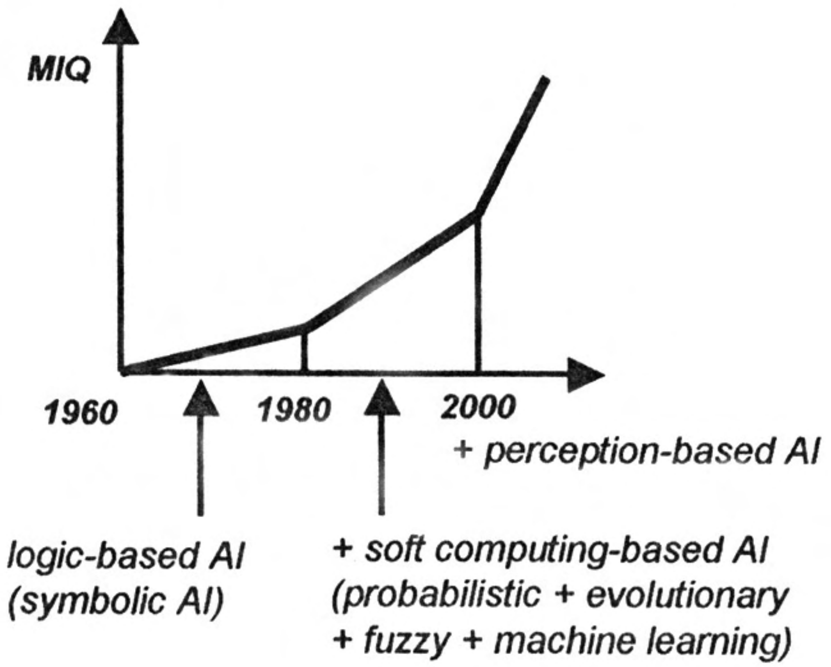
Key methodology: soft computing

SENSOR AFFORDABILITY

Adaptive Logic Announces Availability of the AL220 in ROM Versions EEPROM version prices 30%

San Jose, Calif., April 16, 1996 – Adaptive Logic today is announcing the immediate availability of ROM versions of the AL220, its flagship analog controller. The product will be priced at $1.25 in high volume making it the most cost effective analog controller on the market. As with the EEPROM version the ROM version will be available in 18 PDIP and 20 SOIC packages

TIMELINE OF GROWTH OF MIQ (LAZ)



key methodology: soft computing

core concept in IS: MIQ (Machine Intelligence Quotient)

reformulated goal of AI: realization of intelligent systems with high MIQ

Jules Verne (ca. 1900): scientific progress is driven by exaggerated expectations

WHAT IS SOFT COMPUTING (SC)

Soft computing is a coalition (consortium, partnership, alliance) of computing methodologies which collectively provide a foundation for the conception, design, construction and utilization of information/intelligent systems

The principal members of soft computing are: fuzzy logic (FL), neurocomputing (NC), evolutionary computing (EC) and probabilistic computing (PC)

Members of soft computing are for the most part complementary and symbiotic rather than competitive

EVOLUTION OF AI

From hard computing to soft computing

> *From manipulation of measurements to manipulation of perceptions*

IMPACT OF IT/IST

IT/IST is rapidly emerging as a dominant component of science and technology

IT/IST has a major bearing on economy and economic competiveness

IT/IST has a pronounced impact on culture and social structure

and yet

some of the facets of IT/IST impact are a cause of concern

Employment

The big brother

The curse of efficiency

The crisis of undercoordination

IMPACT ON EMPLOYMENT (US)

IT Responsible for Most Productivity Gains

(Computing Research News, September 2003)

productivity up ⟶ employment down

3 million jobs lost in the United States since 2001

2.2 million jobs lost in manufacturing

20 million jobs in manufacturing in 1980

14 million jobs in manufacturing in 2003

Unemployment down

employment down

THE BIG BROTHER

The new screening program, the Computer Assisted Passenger Profile System (Capps) will seek to determine which passengers will be forbidden to fly on suspicion of terrorism, or at least warrant extra screening. (New York Times, September 27, 2003.)

Jet Blue acknowledged last week that it had turned over information on more than a million passengers, without their knowledge, to a Defense Department contractor

THE CURSE OF EFFICIENCY

The quest for efficiency is driven by

- *competition*
- *maximization of profit*
- *maximization of stock price*
- *enhancement of value of stock options*

Cult of efficiency leads to curse of efficiency

CRISIS OF UNDERCOORDINATION (LAZ 1973)

Scientific progress, and especially progress in information and communication technologies, leads to higher degree of interaction and interdependence

The higher the degree of interaction and interdependence, the greater the need for coordination and control

Highly interdependent systems are vulnerable to catastrophic failures

examples: blackouts air traffic control

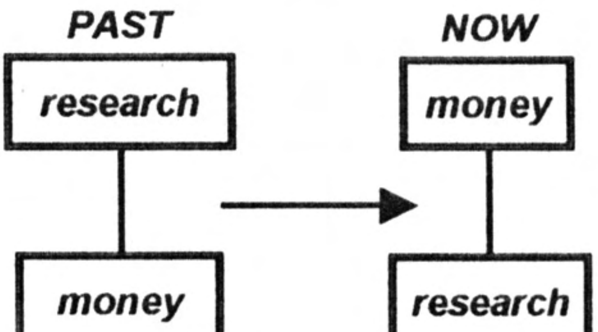
In democratic societies the level of coordination is insufficient because the voters do not like regulation and control

As a consequence, in democratic societies there is a crisis of undercoordination

In this perspective, moves toward deregulation and privatization are—in some cases—moves in the wrong direction

A DISQUIETING TREND

INVERSION OF VALUES



PART B

There is a widening gap Between the status of IT/IST in EU, on one side, and USA and Asia, on the other

TAIWAN (2002)
(SOURCE: DR. C.T. LIN & DR. A. IKEDA)

Population: 23 million

Exports: 131 billion

IT exports: 10 billion

Trade: 243 billion

R&D: 6 billion

Science Park: workforce 100, 000; revenue: 10 billion

IT-related Academic Research Projects Funded by NSC

	Number of Projects	Budget
2001	6000	100 million
2003	7000	120 million

- *National R&D Projects Funded by the Government*
- *Nanoscience and Nanotechnology 2003-2008: 800 million*

JAPAN (Dr. T. Takagi)

Exports (2001): 400 billion

Employment in IT-related Industries:

wide	4 million (2000); 3.9million (2002)
narrow	2.2 million (2000); 2.4 million (2002)

National Institute of Informatics: Budget: 100 million/year

IT RELATED WORKFORCE (%)

	No. of researchers/1k
Taiwan	4.7
USA	10
Japan	7.3
Canada	4.7
Austria	4.8
Korea	2.8
Singapore	3.8
China	.6

TECHNOLOGICAL SUPERIORITY

Technological superiority of the United States in IT/IST is rooted in
(a) Enormous expenditures by the Defense Department
(b) Realization that science is good business

However, there are dark clouds on the horizon

- *In the United States, 5% of students go into engineering*
- *In China, 40% of students go into engineering*
- *Growing fractions of research and manufacturing are outsorced*

SUPPORT OF RESEARCH

In the United States, Department of Defense has played and is continuing to play a major role in supporting both basic and applied research in information technology and intelligent systems

Prominent example of success is the Internet

Defense-Department supported basic research is long range and not linked to military needs or commercial prospects

SOME RELEVANT NUMBERS (US)

IT industry employment: 6.6 million (2000)

IT R&D investment by federal government: 2.05 billion (2003)

NSF budget: 5 billion (2003)
CISE: 527 million

DARPA budget: 2.7 billion (2003)

Defense Advanced:	*6.1: 175 million (basic)*
Research Projects Agency	*6.2:1.24 billion (applied)*
	6.3: 1.22 billion

EDUCATION (US; 2002) (Taulbee Report)

No. of students

- *BS: 23,000*
- *MS: 8,000*
- *Ph.D: 10,000*

Ph.D degrees: 850
Faculty: 5,500

SOME STATISTICS (UC)

Funding of research

- *Federal 64%*
  - *NSF 36%*
  - *NIH 34%*
  - *NASA 10%*
  - *DOD 7%*
- *Foundation 19%*
- *State 8%*
- *Industry2%*

EECS 61 million (2002)
DOD 60%

EXCERPTS FROM A RECENT REPORT FROM THE NATIONAL ACADEMIES (Computer Week 9-22-03)

The federal government's support of information technology research is "essential" and must be raised to meet the growing challenges researchers face, according to a new report from the National Academies' Computer Science and Telecommunications Board

The report, released by the National Academies today, states that agencies such as the National Science Foundation and the Defense Advanced Researched Projects Agency must play larger roles in IT research and must have the government's support to sustain a broad scope of research

Government support for IT research should complement industrial research, the board said. Federal sponsorship of university-based research programs must also continue in order to develop an IT talent base to support future growth in both government and industrial research.