Artificial Intelligence

Our Attempt to Build Models of Ourselves

Elaine Rich
One Vision of an AI
A Calmer Vision
Could AI Stop This?
What is Artificial Intelligence?

A.I. is the study of how to make computers do things at which, at the moment, people are better.
Or, Stepping Back Even Farther, Can We Build Artificial People?

• Historical attempts
• The modern quest for robots and intelligent agents
• Us vs. Them
Historical Attempts - Frankenstein

The original story, published by Mary Shelley, in 1818, describes the attempt of a true scientist, Victor Frankenstein, to create life.

http://members.aon.at/frankenstein/frankenstein-novel.htm
Historical Attempts – The Turk

http://www.theturkbook.com
Historical Attempts - Euphonia

Joseph Faber's Amazing Talking Machine (1830-40's). The Euphonia and other early talking devices are described in detail in a paper by David Lindsay called "Talking Head", *Invention & Technology*, Summer 1997, 57-63.

About this device, Lindsay writes: It is "... a speech synthesizer variously known as the Euphonia and the Amazing Talking Machine. By pumping air with the bellows ... and manipulating a series of plates, chambers, and other apparatus (including an artificial tongue ... ), the operator could make it speak any European language. A German immigrant named Joseph Faber spent seventeen years perfecting the Euphonia, only to find when he was finished that few people cared."

From http://www.haskins.yale.edu/haskins/HEADS/SIMULACRA/euphonia.html
In 1921, the Czech author Karel Capek produced the play *R.U.R.* (Rossum's Universal Robots).

"CHEAP LABOR. ROSSUM'S ROBOTS."
"ROBOTS FOR THE TROPICS. 150 DOLLARS EACH."
"EVERYONE SHOULD BUY HIS OWN ROBOT."
"DO YOU WANT TO CHEAPEN YOUR OUTPUT? ORDER ROSSUM'S ROBOTS"

Some references state that term "robot" was derived from the Czech word *robota*, meaning "work", while others propose that *robota* actually means "forced workers" or "slaves." This latter view would certainly fit the point that Capek was trying to make, because his robots eventually rebelled against their creators, ran amok, and tried to wipe out the human race. However, as is usually the case with words, the truth of the matter is a little more convoluted. In the days when Czechoslovakia was a feudal society, "*robota*" referred to the two or three days of the week that peasants were obliged to leave their own fields to work without remuneration on the lands of noblemen. For a long time after the feudal system had passed away, robota continued to be used to describe work that one wasn’t exactly doing voluntarily or for fun, while today's younger Czechs and Slovaks tend to use robota to refer to work that’s boring or uninteresting.

http://www.maxmon.com/1921ad.htm
The Roots of Modern Technology

5th c B.C.  Aristotelian logic invented

1642  Pascal built an adding machine

1694  Leibnitz reckoning machine
The Roots, continued

1834 Charles Babbage’s Analytical Engine

Ada writes of the engine, “The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform.”

The picture is of a model built in the late 1800s by Babbage’s son from Babbage’s drawings.
The Roots: Logic

1848 George Boole *The Calculus of Logic*

chocolate and \( \neg \) nuts and mint
Mathematics in the Early 20th Century –
(Looking Ahead: Will Logic be the Key to Thinking?)

1900 Hilbert’s program and the effort to formalize mathematics

1931 Kurt Gödel’s paper, On Formally Undecidable Propositions

1936 Alan Turing’s paper, On Computable Numbers with an application to the Entscheidungs problem
The Advent of the Computer

1945 ENIAC  The first electronic digital computer
1949 EDVAC

The first stored program computer
The Dartmouth Conference and the Name Artificial Intelligence

J. McCarthy, M. L. Minsky, N. Rochester, and C. E. Shannon. August 31, 1955. "We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."
1956  Dartmouth conference.

1981  Japanese Fifth Generation project launched as the Expert Systems age blossoms in the US.

1988  AI revenues peak at $1 billion. AI Winter begins.
How Will We Recognize AI?

1950 Alan Turing’s paper, *Computing Machinery and Intelligence*, described what is now called “The Turing Test”. [http://www.abelard.org/turpap/turpap.htm](http://www.abelard.org/turpap/turpap.htm)

1990 Loebner Prize established. Grand Prize of $100,000 and a Gold Medal for the first computer whose responses are indistinguishable from a human.
The Origins of AI Hype

1950    Turing predicted that in about fifty years "an average interrogator will not have more than a 70 percent chance of making the right identification after five minutes of questioning".

1957    Newell and Simon predicted that "Within ten years a computer will be the world's chess champion, unless the rules bar it from competition."
Was Turing Right?

A conversation with Jabberwacky, 2003

Jabberwacky: Have you been to the Moon?
User: No. Few have. Have you?
Jabberwacky: Many a time my dear chap!
User: What was the most interesting thing you saw?
Jabberwacky: Fred.
User: Why did you find him interesting?
Jabberwacky: It just came into my head.
User: What sorts of things do you generally find interesting?
Jabberwacky: Nothing but smelly socks.
> What's the best place to eat Chinese food?

**ALICE:** My favorite places are California and Maine. Holland is cool too.

> What do you like about Maine?

**ALICE:** The special effects are the best.
Alice, Again

>Who invented paper towels?

**ALICE:** The Chinese, long before Europeans.

>Who invented pet rocks?

**ALICE:** The Wright Brothers.

>Who invented Barbie dolls?

**ALICE:** Thomas Edison.
Were Newell and Simon Right?

- 1950 Claude Shannon published a paper describing how a computer could play chess.

- 1957 Newell and Simon predicted that a computer will beat a human at chess within 10 years.

- 1967 MacHack was good enough to achieve a class-C rating in tournament chess.
Chess Today

In 1997, Deep Blue beat Gary Kasparov.
Why Did They Get it Wrong?

They failed to understand at least three key things:

• The need for knowledge (lots of it)

• Scalability and the problem of complexity and exponential growth

• The need to perceive the world
Scalability

Solving hard problems requires search in a large space.

To play master-level chess requires searching about 8 ply deep. So about $35^8$ or $2 \cdot 10^{12}$ nodes must be examined.
Exponential Growth

\[ \text{exp}(x) \]
But Chess is Easy

• The rules are simple enough to fit on one page
• The branching factor is only 35.
A Harder One

John saw a boy and a girl with a red wagon with one blue and one white wheel dragging on the ground under a tree with huge branches.
How Bad is the Ambiguity?

• Kim (1)
• Kim and Sue (1)
• Kim and Sue or Lee (2)
• Kim and Sue or Lee and Ann (5)
• Kim and Sue or Lee and Ann or Jon (14)
• Kim and Sue or Lee and Ann or Jon and Joe (42)
• Kim and Sue or Lee and Ann or Jon and Joe or Zak (132)
• Kim and Sue or Lee and Ann or Jon and Joe or Zak and Mel (469)
• Kim and Sue or Lee and Ann or Jon and Joe or Zak and Mel or Guy (1430)
• Kim and Sue or Lee and Ann or Jon and Joe or Zak and Mel or Guy and Jan (4862)

The number of parses for an expression with \( n \) terms is the \( n \)’th Catalan number:

\[
Cat(n) = \binom{2n}{n} - \binom{2n}{n-1}
\]
Can We Get Around the Search Problem?
How Much Compute Power Does it Take?

How Much Compute Power is There?

Evolution of the Main Ideas

• Wings or not?
• Games, mathematics, and other knowledge-poor tasks
• The silver bullet?
• Knowledge-based systems
• Hand-coded knowledge vs. machine learning
• Low-level (sensory and motor) processing and the resurgence of subsymbolic systems
• Robotics
• Natural language processing
• Programming languages
• Cognitive modeling
Symbolic vs. Subsymbolic AI

Subsymbolic AI: Model intelligence at a level similar to the neuron. Let such things as knowledge and planning emerge.

Symbolic AI: Model such things as knowledge and planning in data structures that make sense to the programmers that build them.

(blueberry (isa fruit) (shape round) (color purple) (size .4 inch))
The Origins of Subsymbolic AI

1943 McCulloch and Pitts *A Logical Calculus of the Ideas Immanent in Nervous Activity*

“Because of the “all-or-none” character of nervous activity, neural events and the relations among them can be treated by means of propositional logic”
Interest in Subsymbolic AI
Low-level (Sensory and Motor) Processing and the Resurgence of Subsymbolic Systems

• Computer vision
• Motor control
• Subsymbolic systems perform cognitive tasks
  • Detect credit card fraud

• The backpropagation algorithm eliminated a formal weakness of earlier systems

• Neural networks learn.
The Origins of Symbolic AI

• Games
• Theorem proving
Games

• Chess

• Checkers:
  • 1952-1962 Art Samuel built the first checkers program
  • Chinook became the world checkers champion in 1994

• Othello:
  • Logistello beat the world champion in 1997
Games

• Chess

• Checkers: Chinook became the world checkers champion in 1994

• Othello: Logistello beat the world champion in 1997

• Go:

• Role Playing Games: now we need knowledge
Mathematics

1956 Logic Theorist (the first running AI program?)

1961 SAINT solved calculus problems at the college freshman level

1967 Macsyma

Gradually theorem proving has become well enough understood that it is usually no longer considered AI

1996 J. Moore and others verified the correctness of the AMD5k86 Floating-Point Division algorithm
The Silver Bullet?

Is there an “intelligence algorithm”?

1957 GPS (General Problem Solver)

Start  Goal
But What About Knowledge?

• Why do we need it?

*Find me stuff about dogs who save people’s lives.*

Around midnight, two beagles spotted a fire in the house next door. Their barking alerted their owners, who called 911.

• How can we represent it and use it?

• How can we acquire it?
1958  McCarthy’s paper, “Programs with Common Sense”

\[
at(I, \text{car}) \Rightarrow \text{can(go(home, airport, driving))}
\]

\[
at(I, \text{desk}) \Rightarrow \text{can(go(desk, car, walking))}
\]

1965  Resolution theorem proving invented
Representing Knowledge- Semantic Nets

1961
Representing Knowledge – Capturing Experience

Representing Experience with Scripts, Frames, and Cases

1977 Scripts

Joe went to a restaurant. Joe ordered a hamburger. When the hamburger came, it was burnt to a crisp. Joe stormed out without paying.

The restaurant script:

Did Joe eat anything?
Representing Knowledge - Rules

Expert knowledge in many domains can be captured in rules.

From XCON (1982):

*If* the most current active context is distributing massbus devices, and there is a single-port disk drive that has not been assigned to a massbus, and there are no unassigned dual-port disk drives, and the number of devices that each massbus should support is known, and there is a massbus that has been assigned at least one disk drive that should support additional disk drives, and the type of cable needed to connect the disk drive to the previous device on the massbus is known

*Then*: assign the disk drive to the massbus.
Representing Knowledge – Probabilistically

1975  Mycin attaches probability-like numbers to rules

   *If: (1) the stain of the organism is gram-positive, and* 
   * (2) the morphology of the organism is coccus, and* 
   * (3) the growth conformation of the organism is clumps*

   *Then: there is suggestive evidence (0.7) that the identity of* 
   *the organism is stphylococcus.*

1970s  Probabilistic models of speech recognition

1980s  Statistical Machine Translation systems

1990s  Large scale neural nets
The Rise of Expert Systems

1967  Dendral – a rule-based system that inferred molecular structure from mass spectral and NMR data

1975  Mycin – a rule-based system to recommend antibiotic therapy

1975  Meta-Dendral learned new rules of mass spectrometry, the first discoveries by a computer to appear in a refereed scientific journal

1979  EMycin – the first expert system shell

1980’s  The Age of Expert Systems
Expert Systems – The Heyday

1979  Inference
1980  IntelliCorp
1981  Teknowledge
1983  Carnegie Group

Selling expert system shells

1980  XCON (R1) – first real commercial expert system at DEC, configures VAX systems

1981  Japanese Fifth Generation project launched as the Expert Systems age blossoms in the US.

1984  Gold Hill Common Lisp
1986  neural net start up companies appear

1988  AI revenues peak at $1 billion. AI Winter begins.
Expert Systems – Today: Medicine

One example domain, medicine, has expert systems whose tasks include:

• arrhythmia recognition from electrocardiograms
• coronary heart disease risk group detection
• monitoring the prescription of restricted use antibiotics
• early melanoma diagnosis
• gene expression data analysis of human lymphoma
• breast cancer diagnosis
Expert Systems – Today: Build Your Own

eXpertise2Go:  http://www.expertise2go.com/

AcquiredIntelligence:  http://www.aiinc.ca/demos/

(whales, graduate school)
QUESTION: Sodium azide is used in air bags to rapidly produce gas to inflate the bag. The products of the decomposition reaction are: (a) Na and water. (b) Ammonia and sodium metal. (c) N2 and O2 (d) Sodium and nitrogen gas. (e) Sodium oxide and nitrogen gas.

(d) Sodium and nitrogen gas.
What are the products of the given decomposition reaction?

- By definition, oxidation-reduction reactions occur when electrons are transferred from the atom that is oxidized to the atom that is reduced. We need to look for changes in the oxidation states of the elements in the reaction.
  - In the reactants, the oxidation state(s) of the element Na is/are (1). In the product, the oxidation state(s) is/are (0).
  - Therefore, the reaction causes a change in oxidation state.
  - Therefore, this is an oxidation reduction reaction.
- By definition, a Binary Ionic-Compound Decomposition Reaction occurs when a binary ionic compound is heated.
- Therefore, this reaction is a Binary-Ionic Compound Decomposition reaction.
- In general, a Binary Ionic-Compound Decomposition Reaction converts a binary ionic-compound into basic elements.
- In this reaction, NaN₃ reacts to produce Na and N₂.

The products of the decomposition reaction are:

(d) Sodium and nitrogen gas.

The work of Bruce Porter et al here at UT
What About Things that People Do *Easily*?

• Common sense

• Moving Around

• Language
What About Things that People Do *Easily*?

• Common sense
  • CYC
• Moving around

• Language
Hand-Coded Knowledge vs. Machine Learning

• How much work would it be to enter knowledge by hand?
• Do we even know what to enter?

1952-62  Samuel’s checkers player learned its evaluation function
1975  Winston’s system learned structural descriptions from examples and near misses

1984  Probably Approximately Correct learning offers a theoretical foundation

mid 80’s  The rise of neural networks
1950 W. Grey Walter’s light seeking tortoises. In this picture, there are two, each with a light source and a light sensor. Thus they appear to “dance” around each other.
Robotic – Hopkins Beast

1964 Two versions of the Hopkins beast, which used sonar to guide it in the halls. Its goal was to find power outlets.
1970  Shakey (SRI) was driven by a remote-controlled computer, which formulated plans for moving and acting. It took about half an hour to move Shakey one meter.
Robotics – Stanford Cart

1971-9 Stanford cart.
Remote controlled by person or computer.

1971 follow the white line

1975 drive in a straight line by tracking skyline

1979 get through obstacle courses. Cross 30 meters in five hours, getting lost one time out of four
Planning vs. Reacting

In the early days: substantial focus on planning (e.g., GPS)

1979 – in “Fast, Cheap and Out of Control”, Rodney Brooks argued for a very different approach. (No, I’m not talking about the 1997 movie.)

The Ant, has 17 sensors.
They are designed to work in colonies.

http://www.ai.mit.edu/projects/ants/
1994 Dante II (CMU) explored the Mt. Spurr (Aleutian Range, Alaska) volcano. High-temperature, fumarole gas samples are prized by volcanic science, yet their sampling poses significant challenge. In 1993, eight volcanologists were killed in two separate events while sampling and monitoring volcanoes.

Using its tether cable anchored at the crater rim, Dante II is able to descend down sheer crater walls in a rappelling-like manner to gather and analyze high temperature gasses from the crater floor.
Robotics - Sojourner

Oct. 30, 1999 Sojourner on Mars. Powered by a 1.9 square foot solar array, Sojourner can negotiate obstacles tilted at a 45 degree angle. It travels at less than half an inch per second.

http://antwrp.gsfc.nasa.gov/apod/ap991030.html
Robotics – Mars Rover

Tutorial on Rover:
Sandstorm

March 13, 2004 - A DARPA Grand Challenge: an unmanned offroad race, 142 miles from Barstow to Las Vegas.
Moving Around and Picking Things Up

Phil, the drug robot, introduced in 2003
Robotics - Aibo

1999 Sony’s Aibo pet dog
What Can You Do with an Aibo?

1997 – First official Rob-Cup soccer match

Picture from 2003 competition
1998 – now  Cog

*Humanoid intelligence requires humanoid interactions with the world.*

At the Other End of the Spectrum - Roomba

2001 A robot vacuum cleaner
1964 STUDENT solves algebra word problems

The distance from New York to Los Angeles is 3000 miles. If the average speed of a jet plane is 600 miles per hour, find the time it takes to travel from New York to Los Angeles by jet.

1965 ELIZA models a Rogerian therapist

young woman: Men are all alike.

eliza: In what way?

young woman: They're always bugging us about something specific or other.

eliza: Can you think of a specific example?

young woman: Well, my boyfriend made me come here.

eliza: Your boyfriend made you come here?
NLP, continued

1966  Alpac report kills work on MT

1971  SHRDLU
NLP, continued

1973  Schank – a richer limited domain: children’s stories

*Suzie was invited to Mary’s birthday party. She knew she wanted a new doll so she got it for her.*

1977  Schank – scripts add a knowledge layer – restaurant stories

1970’s and 80’s  sophisticated grammars and parsers

But suppose we want generality? One approach is “shallow” systems that punt the complexities of meaning.
NLP Today

• Grammar and spelling checkers
  • Spelling: http://www.spellcheck.net/

• Chatbots
  • See the list at: http://www.aaai.org/AITopics/html/natlang.html#chat/

• Speech systems
  • Synthesis: The IBM system:
    • http://www.research.ibm.com/tts/coredemo.html
Machine Translation: An Early NL Application

1949  Warren Weaver’s memo suggesting MT
1966  Alpac report kills government funding
Early 70s  SYSTRAN develops direct Russian/English system
Early 80s  knowledge based MT systems
Late 80s  statistical MT systems
Austin Police are trying to find the person responsible for robbing a bank in Downtown Austin.

*El policía de Austin está intentando encontrar a la persona responsable de robar un banco en Austin céntrica.*

The police of Austin is trying to find the responsible person to rob a bank in centric Austin.
A Florida teen charged with hiring an undercover policeman to shoot and kill his mother instructed the purported hitman not to damage the family television during the attack, police said on Thursday.

Un adolescente de la Florida cargado con emplear a un policía de la cubierta interior para tirar y para matar a su madre mandó a hitman pretendida para no dañar la televisión de la familia durante el ataque, limpia dicho el jueves.

An adolescent of Florida loaded with using a police of the inner cover to throw and to kill his mother commanded to hitman tried not to damage the television of the family during the attack, clean said Thursday.
I have a dream, that my four little children will one day live in a nation where they will not be judged by the color of their skin but by the content of their character. I have a dream today – Martin Luther King

I am a sleepy, that my four small children a day of alive in a nation in where they will not be judged by the color of its skin but by the content of its character. I am a sleepy today. (Spanish)

http://www.shtick.org/Translation/translation47.htm
Why Is It So Hard?

Sue caught the bass with her new rod.
Why Is It So Hard?

Sue caught (the bass) (with her new rod).
Why Is It So Hard?

Sue caught the bass with the dark stripes.
Why Is It So Hard?

Sue caught (the bass with the dark stripes).
Why Is It So Hard?

Sue played the bass with her new bow.
Why Is It So Hard?

Sue played the bass with her new bow.

Sue played the bass with her new beau.
Why Is It So Hard?

Olive oil
Why Is It So Hard?

Olive oil
Why Is It So Hard?

Peanut oil
Why Is It So Hard?

Coconut oil
Why Is It So Hard?

Baby oil
Why Is It So Hard?

Cooking oil
MT Today

Is MT an “AI complete” problem?

• John saw a bicycle in the store window. He wanted it.
• John saw a bicycle in the store window. He pressed his nose up against it.

• John saw the Statue of Liberty flying over New York.
• John saw a plane flying over New York.
Text Retrieval and Extraction

• Try Ask Jeeves: http://www.askjeeves.com

• To do better requires:
  • Linguistic knowledge
  • World knowledge

• Newsblaster: http://www1.cs.columbia.edu/nlp/newsblaster/
Programming Languages

1958  Lisp – a functional programming language with a simple syntax.

\[(successor\ SitA\ ActionP)\]

1972  PROLOG - a logic programming language whose primary control structure is depth-first search

\[
\begin{align*}
\text{ancestor}(A,B) & :\text{ parent}(A,B) \\
\text{ancestor}(A,B) & :\text{ parent}(A,P), \text{ ancestor}(P,B)
\end{align*}
\]

1988  CLOS (Common Lisp Object Standard) published.
Draws on ideas from Smalltalk and semantic nets
Cognitive Modeling

Symbolic Modeling

1957  GPS

1983  SOAR

Neuron-Level Modeling

McCulloch Pitts neurons: all or none response

More sophisticated neurons and connections

More powerful learning algorithm
Making Money – Software

• Expert systems to solve problems in particular domains
• Expert system shells to make it cheaper to build new systems in new domains
• Language applications
  • Text retrieval
  • Machine Translation
  • Text to speech and speech recognition
• Data mining
Making Money - Hardware

1980  Symbolics founded

1986  Thinking Machines introduces the Connection Machine

1993  Symbolics declared bankruptcy

Symbolics 3620 System c 1986:
Up to 4 Mwords (16 Mbytes) optional physical memory, one 190 Mbyte fixed disk, integral Ethernet interface, five backplane expansion slots, options include an additional 190 Mbyte disk or 1/4" tape drive, floating point accelerator, memory, RS232C ports and printers.
Making Money - Robots

1962  Unimation, first industrial robot company, founded. Sold a die casting robot to GM.

1990  iRobot founded, a spinoff of MIT

2000  The UN estimated that there are 742,500 industrial robots in use worldwide. More than half of these were being used in Japan.

2001  iRobot markets Roomba for $200.
The Differences Between Us and Them

Emotions

Understanding

Consciousness
Emotions

The robot Kismet shows emotions

sad                       surprise

http://www.ai.mit.edu/projects/humanoid-robotics-group/kismet/
Understanding

Searle’s Chinese Room
Consciousness

Me

You
Today: The Difference Between Us and Them
Today: Computer as Artist

Two paintings done by Harold Cohen’s Aaron program:
"AI can have two purposes. One is to use the power of computers to augment human thinking, just as we use motors to augment human or horse power. Robotics and expert systems are major branches of that. The other is to use a computer's artificial intelligence to understand how humans think. In a humanoid way. If you test your programs not merely by what they can accomplish, but how they accomplish it, you're really doing cognitive science; you're using AI to understand the human mind."

- Herb Simon