HUMAN-LEVEL ARTIFICIAL INTELIGENCE & COGNITIVE SCIENCE

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OUTLINE

Computation and Intelligence

Approaches Toward HLAI

The Current Situation

THE COMPUTER: A UNIVERSAL MACHINE

"It can be shown that a single special machine of that type [a Turing machine] can be made to do the work of all. It could in fact be made to work as a model of any other machine. The special machine may be called the universal machine."

—Alan Turing

"The importance of the universal machine is clear. We do not need to have an infinity of different machines doing different jobs. A single one will suffice. The engineering problem of producing various machines for various jobs is replaced by the office work of 'programming' the universal machine to do these jobs."

—Alan Turing

"[Turing] decided the scope of the computable encompassed far more than could be captured by explicit instruction notes, and quite enough to include all that human brains did, however creative or original."

—Andrew Hodges, a Turing Biographer

THE PHYSICAL SYMBOL SYSTEM HYPOTHESIS (PSSH)

"A physical symbol system [i.e., a computer] has the necessary and sufficient means for intelligent action."

—Allen Newell and Herbert Simon

Relevance to Cognitive Science:
Computational processes can explain (be a theory of) human intelligence.

Relevance to AI:
Computational processes can implement human intelligence.

But, it's just a hypothesis!

THE NAYSAYERS CLAIM (Among Other Things) "THE BRAIN IS NOT A COMPUTER!"

Computation:
- mainly serial
- 10^9 ops/sec
- 10^9 transistors
- digital/discrete (even binary!)
- disembodied
- silicon
- subject to crashes
- . . .

The Brain:
- highly parallel
- 10^3 ops/sec
- 10^{14} neurons; 10^{17} synapses
- analog/continuous
- embodied
- protein
- fault-tolerant
- . . .

WHAT IS A COMPUTER? WHAT IS A BRAIN?

CAN COMPUTATIONAL SYSTEMS BE INTELLIGENT?

HOW WOULD WE KNOW?

The Turing Test

The “Employment” Test

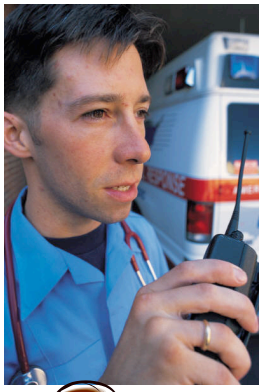
SOME JOBS THAT HUMANS PERFORM*

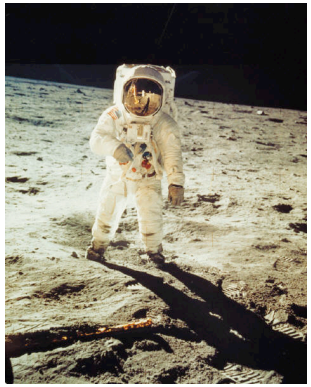
Meeting and Convention Planner
Maid and Housekeeping Cleaner
Receptionist
Financial Examiner
Computer Programmer
Roofer's Helper
Library Assistant
Procurement and Sales Engineer
Farm, Greenhouse, Nursery Worker
Dishwasher
Home Health Aide

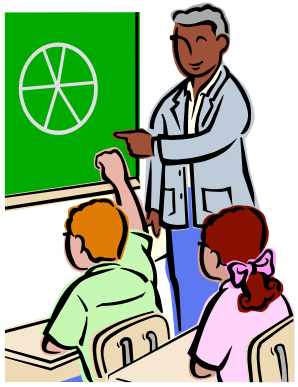
Small Engine Repairer
Paralegal
Lodging Manager
Proofreader
Tour Guide and Escort
Geographer
Engine and Other Machine Assembler
Security Guard
Retail Salesperson
Marriage and Family Counselor
Hand Packer and Packager

CAN THEY BE AUTOMATED?

*From "America's Job Bank," a list of more than 1,500 jobs.
Available at www.jobsearch.org/help/employer/SSONetJobCodeListbyCategory2.html







HOW TO PROCEED?

LET'S LOOK AT SOME THINGS AI HAS TRIED

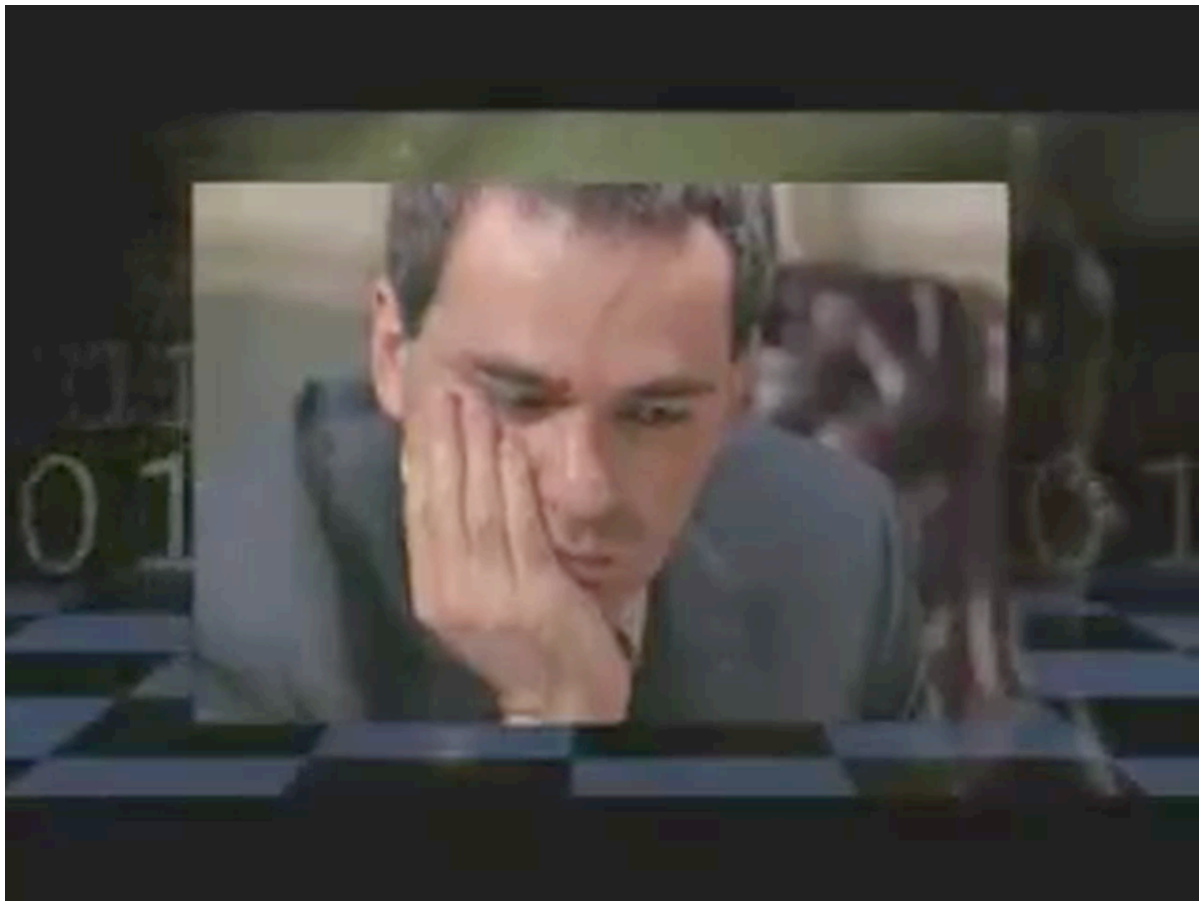
THINGS AI HAS TRIED

- Try to program some activities thought to require intelligence
- Try to program some fundamental processes thought to be involved in intelligence
- Try to imitate the brain
- Try to simulate the performance of ever more complex biological organisms
- Try to simulate biological evolution
- Try to “educate” simple (child-like) programs to make them more intelligent and capable

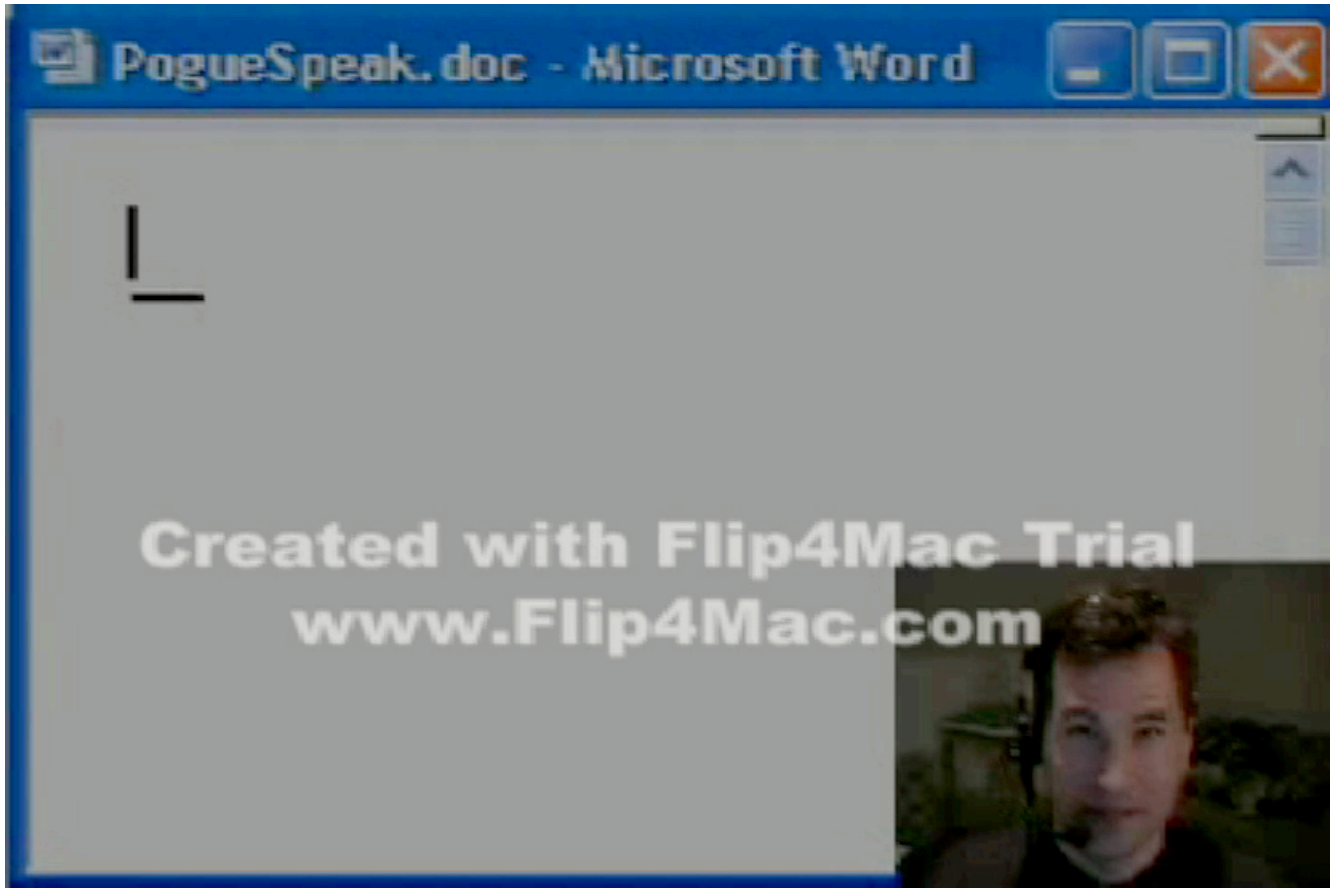
1. Programming Activities That Require Intelligence

Game playing
Theorem proving
Pattern recognition (images, speech, . . .)
Natural language understanding
Autonomous activity
    (robots that can perceive, plan and act)
Expert judgment
. . .

Game-Playing



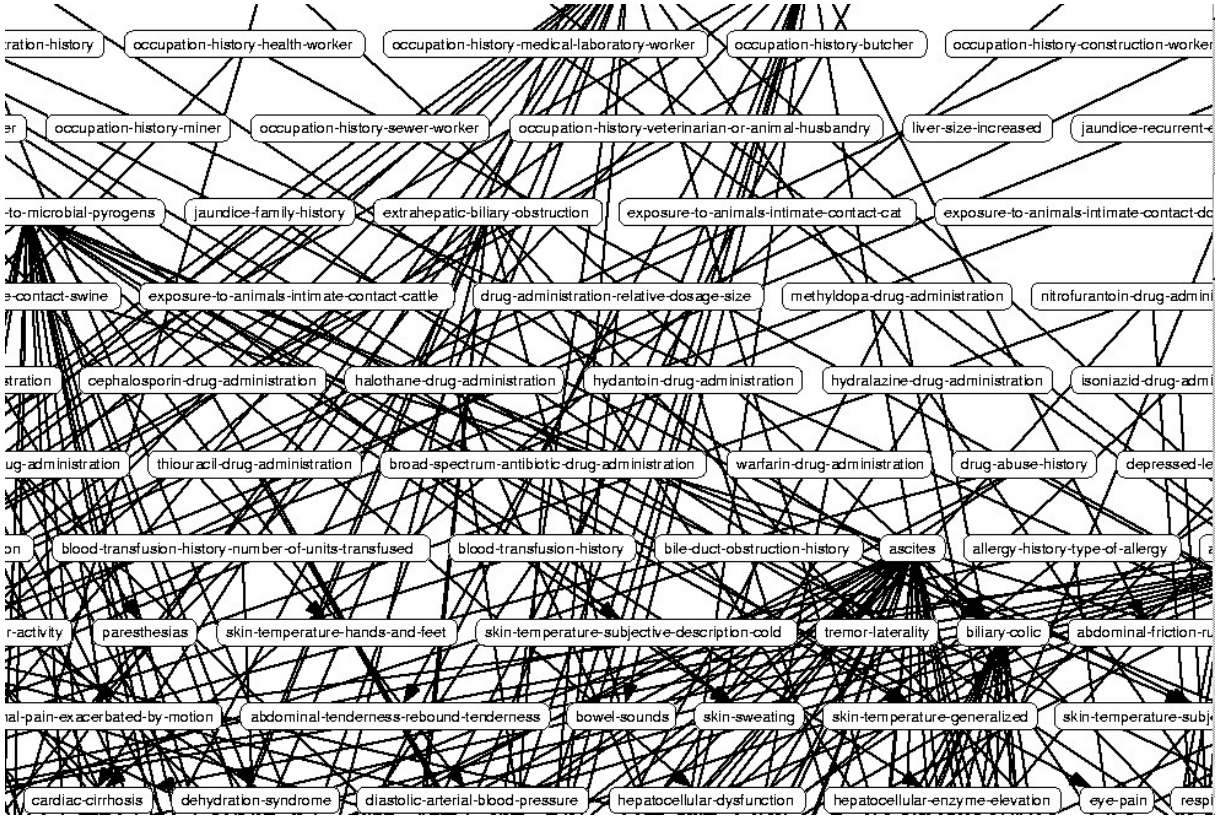
Speech Recognition



Autonomous Activity

Autonomous Activity

Expert Judgment



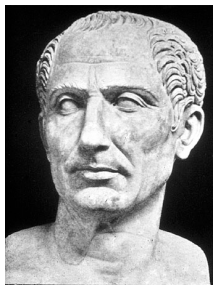
Part of a Large Bayesian Network
Used for the Diagnosis of Hepatobiliary Diseases

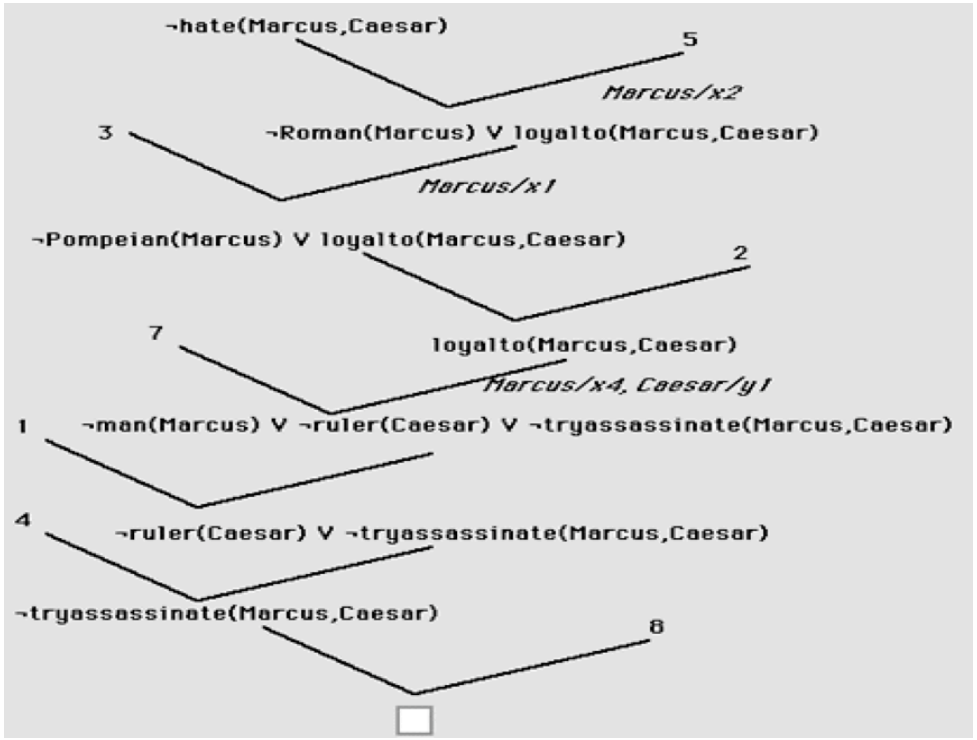
WOULD SOME COMBINATION OF ALL OF THESE SKILLS ADD UP TO HLAI?

2. Programming Processes Thought to be Involved in Intelligence

Logical reasoning
Probabilistic reasoning
Search
Image processing
Knowledge representation
Learning
Syntactic analysis
Planning
. . .

Logical Reasoning



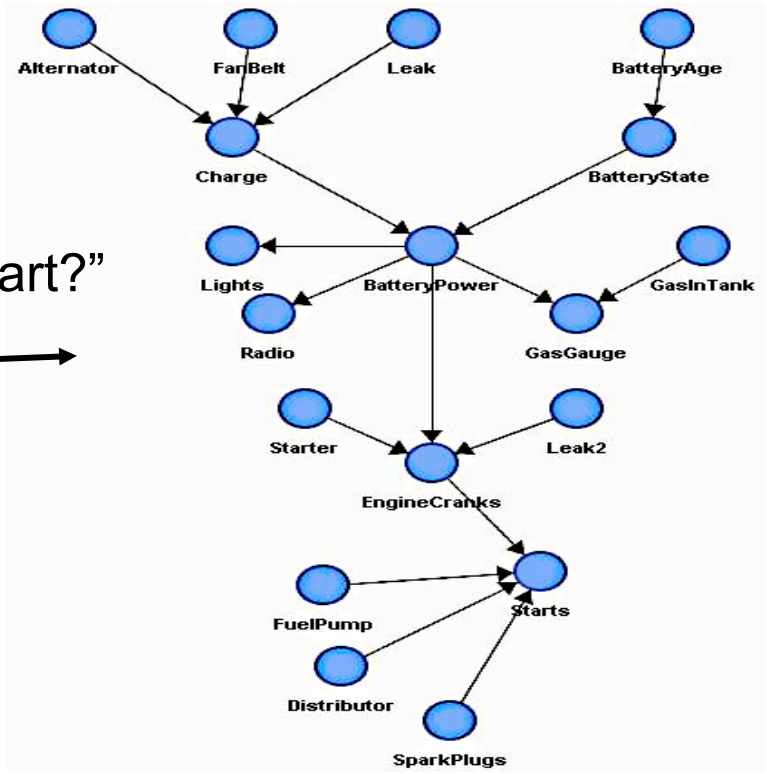


Resolution Theorem Proving

Propositional Satisfiability (SAT)

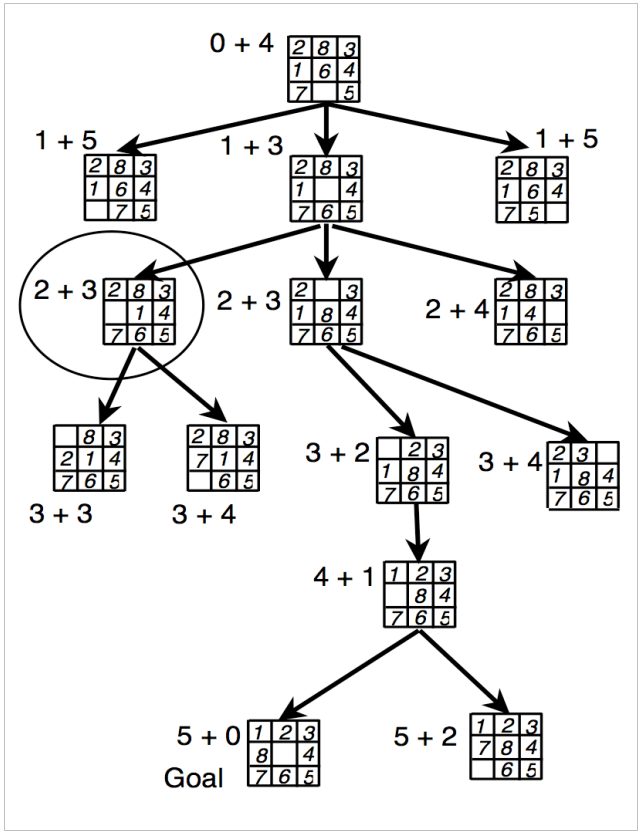
Probabilistic Reasoning

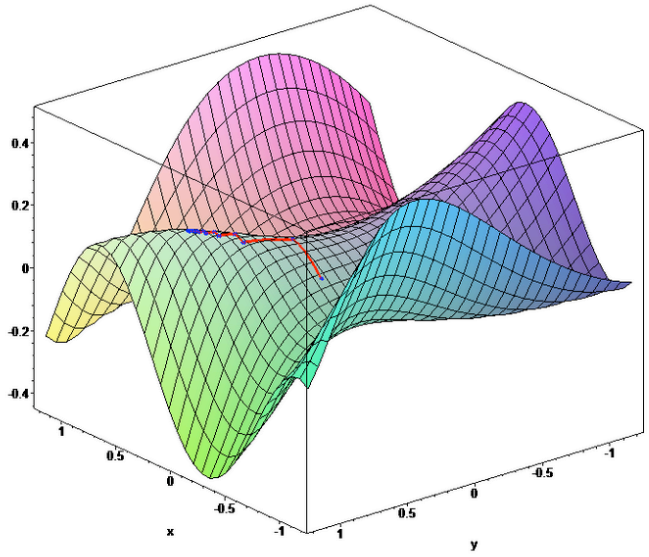
"Why won't the car start?"



Bayesian Belief Networks

Search

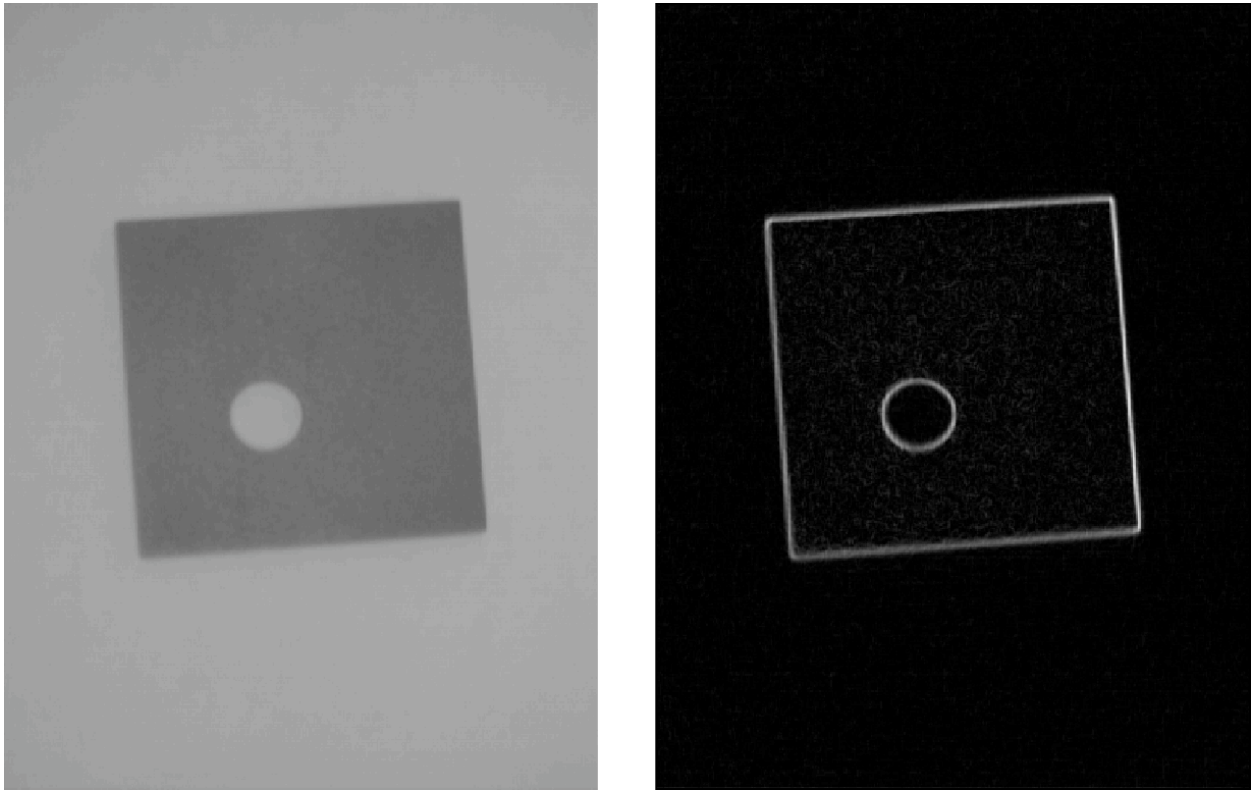




A*, Hill-Climbing

Recursive Back-Tracking

Image Processing

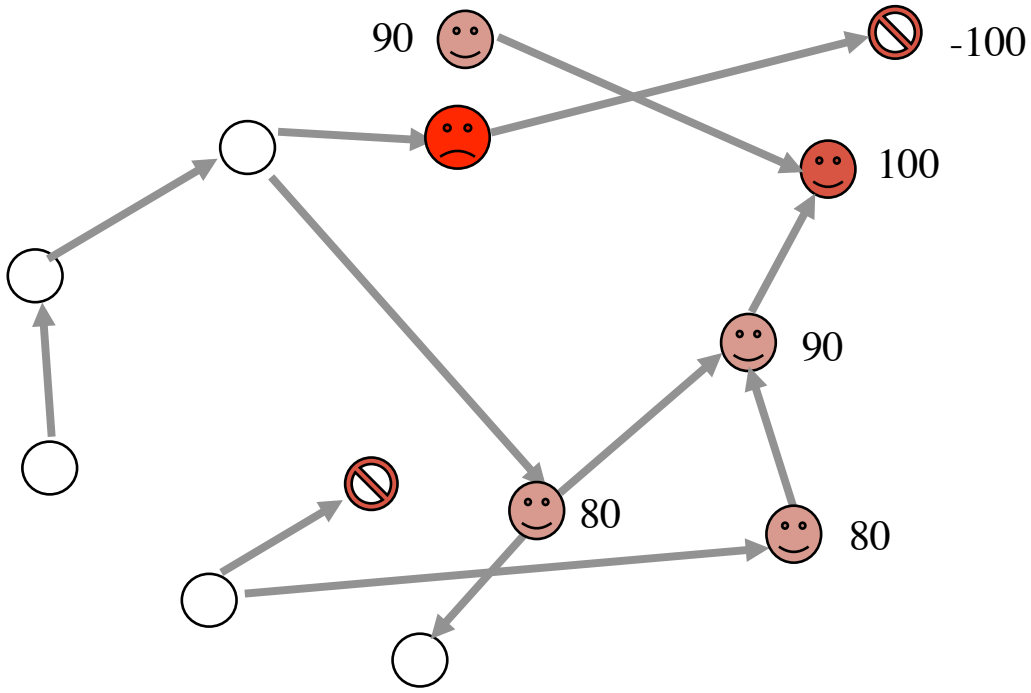


E. g., Edge Extraction

Representing Knowledge

Semantic Networks, Cyc, WordNet

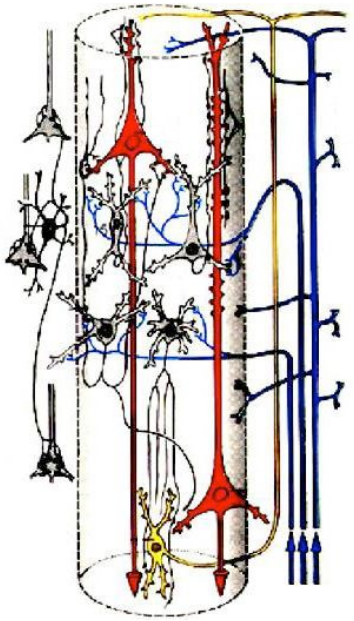
Learning



E. g., Reinforcement Learning

WOULD SOME COMBINATION OF PROCESSES LIKE THESE PRODUCE HLAI?

3. Trying to Imitate the Brain



Neural Networks

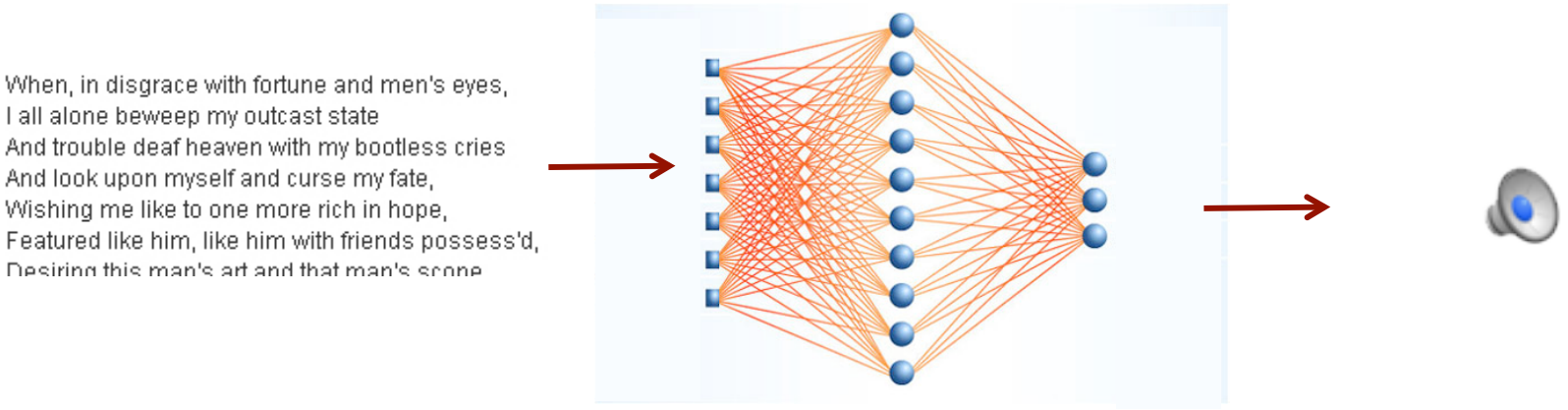
Models of the Neo-Cortex

Neural Networks

Input: Text Versions of English Words

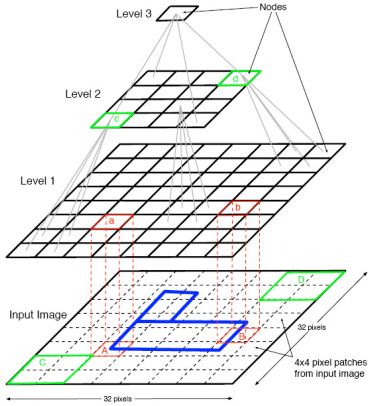
Output: Sound

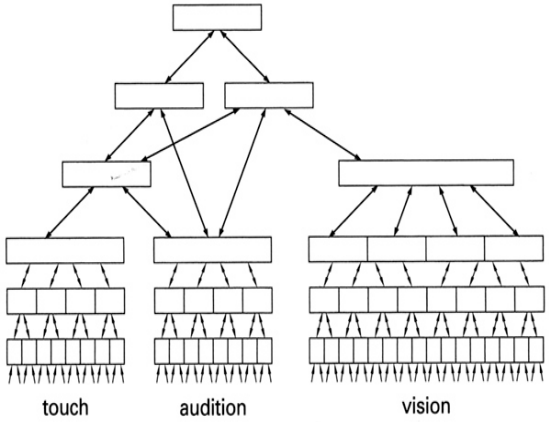
Training: Change Weights to Make Sound More Correct

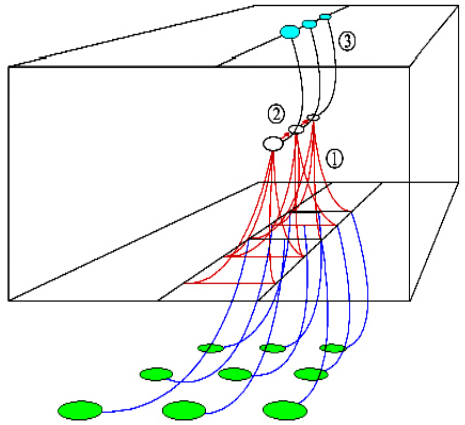


Sejnowski, T. J. and Rosenberg, C. R., Parallel networks that learn to pronounce English text, Complex Systems 1, 145-168 (1987).

Models of Neo-Cortex







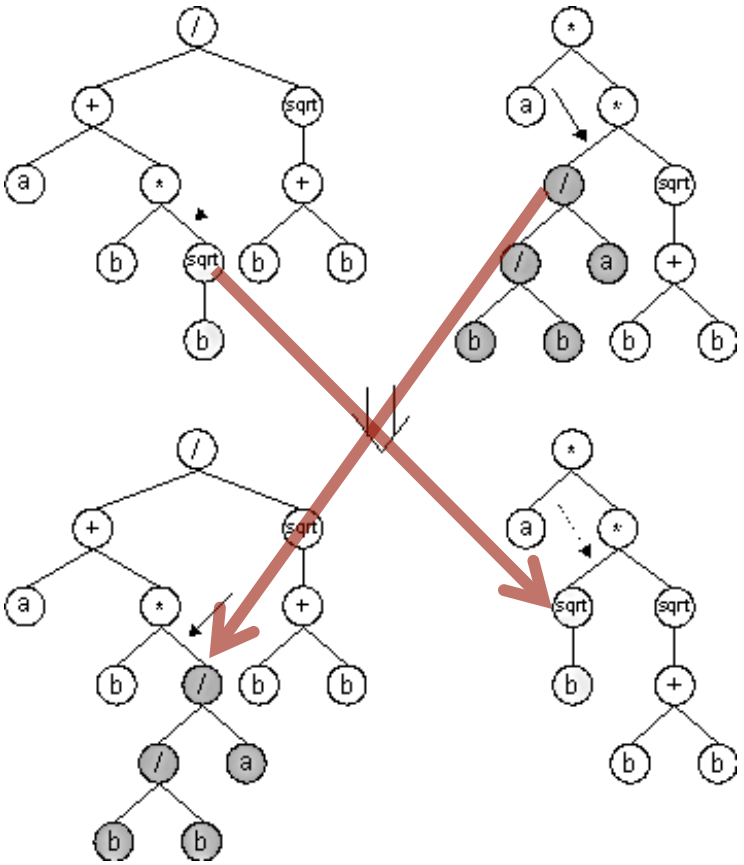
Large Graphical Models

Jeff Hawkins, Tom Dean, David Mumford, Geoff Hinton, . . .

4. Simulating Simple Biological Organisms

Rod Brooks's Creepy-Crawly Things

5. Simulating Biological Evolution



Target-Seeking Demo

http://www.cs.northwestern.edu/~fjs750/netlogo/final/gpdemo.html

Truck-Backing Demo

http://www.handshake.de/user/blickle/Truck/index.html

Genetic Algorithms, Genetic Programming

6. “Educating” Educable Programs

Turing’s “Child Programme”

Cassimatis’s “Cognitive Substrate”

Lenat’s “CYC Bootstrapping”

WHICH OF THESE APPROACHES WILL BE SUCCESSFUL?

WE'LL HAVE TO WAIT AND SEE!

IN THE MEANTIME:

THESE EFFORTS HAVE PRODUCED A GROWING ARMAMENTARIUM OF TECHNICAL TOOLS

Here is a Partial List:

Bayesian Belief Networks
Hidden Markov Models
Kalman Filtering
POMDP's
A* Global Search
Hill-Climbing Local Search
GA/GP
Resolution Theorem Prvg.
SAT Encodings/Solvers
Semantic Networks
Reinforcement Learning

Neural Networks
Backpropagation
Support Vector Machines
Blackboard Architectures
Monte Carlo Methods
Statistical Grammars
Expectation Maximization
Inductive Logic Programming
Teleo-Reactive Programs
Particle Filtering
Model-Based Vision

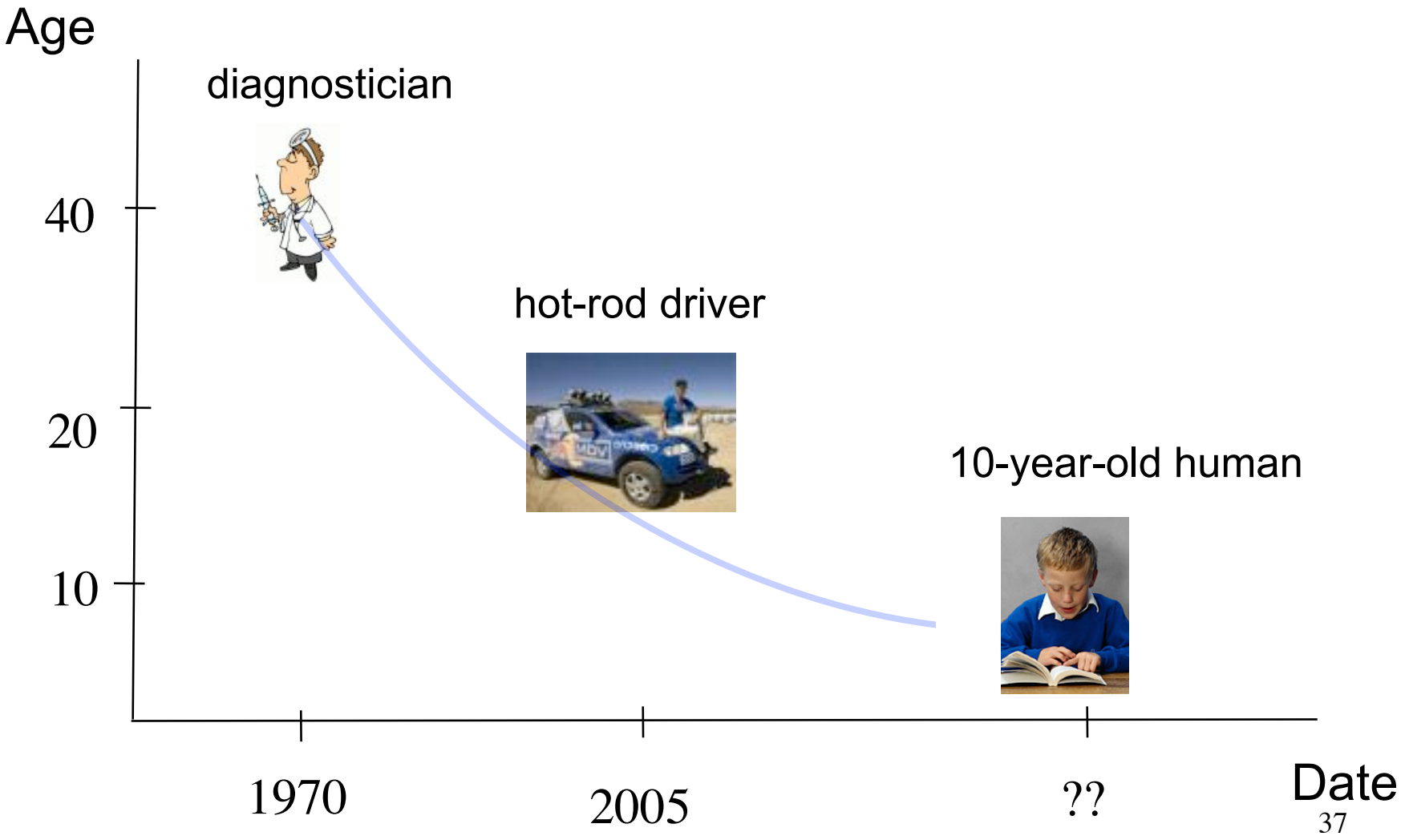
Will They Help Us Achieve HLAI? Are More Tools Needed?

THE CURRENT SITUATION

The Tools Are Being Used to Solve Problems in Several Fields:

Biology
Genomics
Chemistry
Medicine
Aeronautics
Geology
Data Mining
Business
. . .

But Little Work is Being Done Toward HLAI. Why?

PETER HART'S QUESTION

(AI's Progress)