AI Applications

CPSC322 Lecture 3

R&R systems we'll cover in this course

		Environment	
Problem		**Deterministic**	**Stochastic**
Static	Constraint Satisfaction	*Variables + Constraints* Search Arc Consistency Local Search	
	Query	*Logics* Search	*Bayesian (Belief) Networks* Variable Elimination
Sequential	Planning	*STRIPS* Search	*Decision Networks* Variable Elimination

Representation
Reasoning Technique

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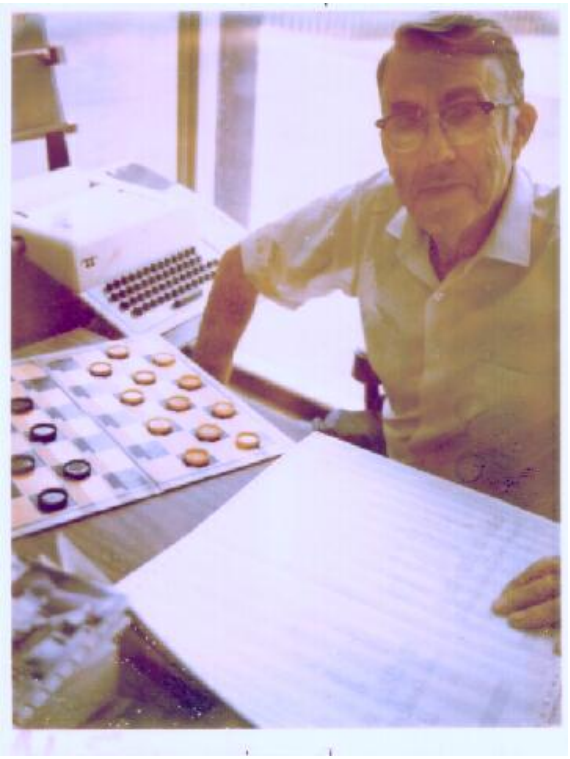
Representation
Reasoning Technique

(Adversarial) Search: Checkers

Game playing was one of the first tasks undertaken in AI

Arthur Samuel at IBM wrote programs to play checkers (1950s)

- initially, they played at a strong amateur level
- however, they used some (simple) machine learning techniques, and soon outperformed Samuel



Source: *IBM Research*

Chinook's program was declared the Man-Machine World Champion in checkers in 1994!

…and **<u>completely solved</u>** by a program in 2007!

(Adversarial) Search: Chess

In 1996 and 1997, Gary Kasparov, the world chess grandmaster played two tournaments against Deep Blue, a program written by researchers at IBM

Source: *IBM Research*

(Adversarial) Search: Chess

Deep Blue's Results in the first tournament:

- won 1 game, lost 3 and tied 1
  - ✓first time a reigning world champion lost to a computer

Source: *CNN*

(Adversarial) Search: Chess

Deep Blue's Results in the second tournament:

- second tournament: won 3 games, lost 2, tied 1

- 30 CPUs + 480 chess processors
- Searched 126,000,000 nodes per sec
- Generated 30 billion positions per move reaching depth 14 routinely

Sample A* applications

- **An Efficient A* Search Algorithm For Statistical** Machine Translation. (2001)
- **The Generalized A* Architecture**. *Journal of Artificial Intelligence Research* (2007)
  - Machine Vision
- **Factored A*search for models over sequences and trees.** *International Conference on AI* (2003)
  - applied to NLP and BioInformatics
- **Finding shortest paths on real road networks: the case for A*.** *International Journal of Geographical Information Science* (2009)

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Representation
Reasoning Technique

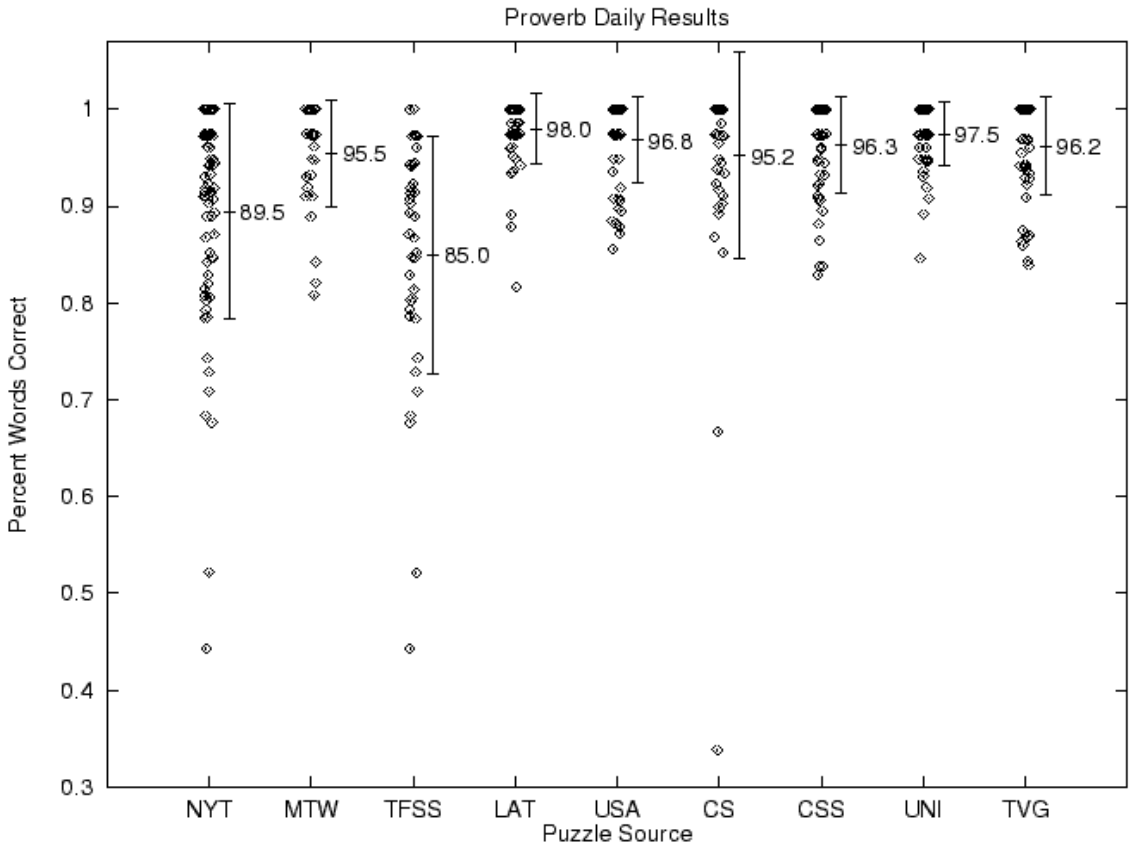
CSPs: Crossword Puzzles

Daily Puzzles

370 puzzles from 7 sources.

Summary statistics:

- 95.3% words correct (miss three or four words per puzzle)
- 98.1% letters correct
- 46.2% puzzles completely correct



P	O	L	O	N	E	■	P	A	L	O	M	I	N	O
A	S	I	M	O	V	■	I	S	O	L	A	T	E	D
S	L	E	E	V	E	■	T	H	W	A	R	T	E	D
T	I	G	G	E	R	■	C	O	R	N	Y	■	■	■
A	N	E	A	L	E	■	A	R	I	D	■	J	A	M
■	■	■	■	E	S	P	I	E	S	■	L	O	G	O
S	E	A	O	T	T	E	R	■	E	E	E	N	O	N
A	B	B	O	T	■	A	N	A	■	U	S	A	G	E
B	O	O	Z	E	S	■	S	N	A	P	S	H	O	T
E	N	V	Y	■	P	L	I	N	T	H	■	■	■	■
R	Y	E	■	H	I	E	S	■	T	E	A	S	E	T
■	■	■	K	A	R	E	L	■	I	M	P	A	L	E
M	A	R	I	N	A	R	A	■	M	I	A	S	M	A
A	B	E	R	D	E	E	N	■	E	S	C	H	E	R
S	H	N	K	Y	A	R	D	■	S	M	E	A	R	S

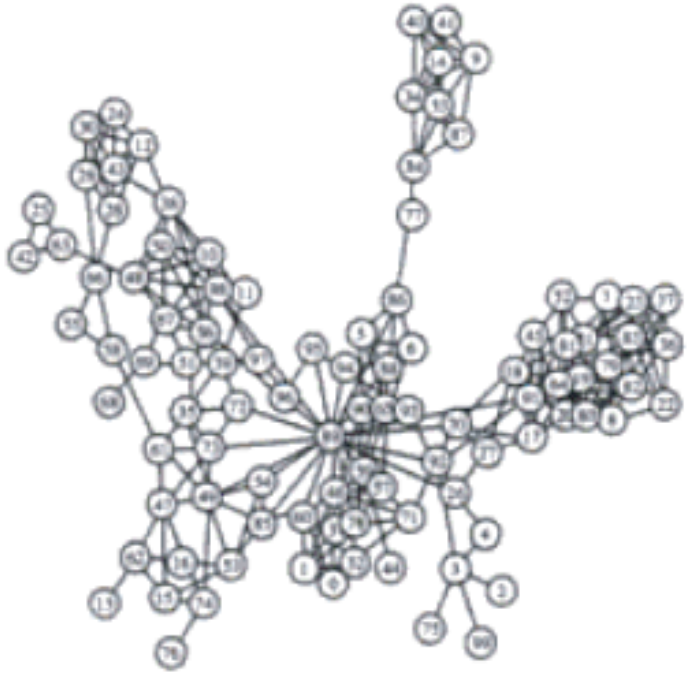
Source: *Michael Littman*

CSPs: Radio link frequencies

Assigning frequencies to a set of radio links defined between pairs of sites in order **to avoid interference**.

Constraints on frequency depend on **position of the links** and on **physical environment** .

Source: *INRIA*



Example: RNA secondary structure design

RNA strand made up of four bases: cytosine (C), guanine (G), adenine (A), and uracil (U)

2D/3D structure RNA strand folds into is important for its function

RNA strand

GUCCCAUAGGAUGUCCCAUAGGA

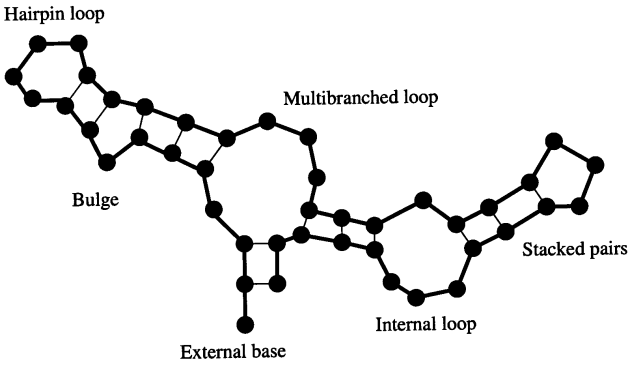
Predicting structure for a strand is "easy": $O(n^3)$

Easy

Hard

But what if we want a strand that folds into a certain structure?

Secondary structure



One of the best algorithms to date: Local search algorithm RNA-SSD developed at UBC [Andronescu, Fejes, Hutter, Condon, and Hoos, Journal of Molecular Biology, 2004]

Constraint optimization problems

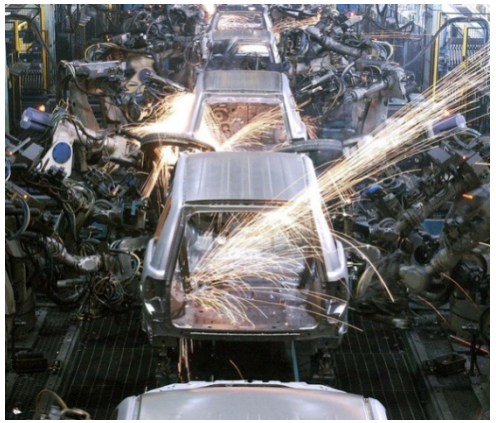
Optimization under constraints (similar to CSP)

E.g. mixed integer programming (software: IBM CPLEX)

- Linear program: max $c^T x$ such that $Ax \leq b$
- Mixed integer program: additional constraints, $x_i \in \mathbb{Z}$ (integers)
- NP-hard, widely used in operations research and in industry

Transportation/Logistics:
SNCF, United Airlines
UPS, United States Postal Service, …

Supply chain management software:
Oracle, SAP,…



Production planning and optimization:
Airbus, Dell, Porsche, Thyssen Krupp, Toyota, Nissan, ...

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Representation
Reasoning Technique

CSP/logic: formal verification

Hardware verification
(e.g., IBM)

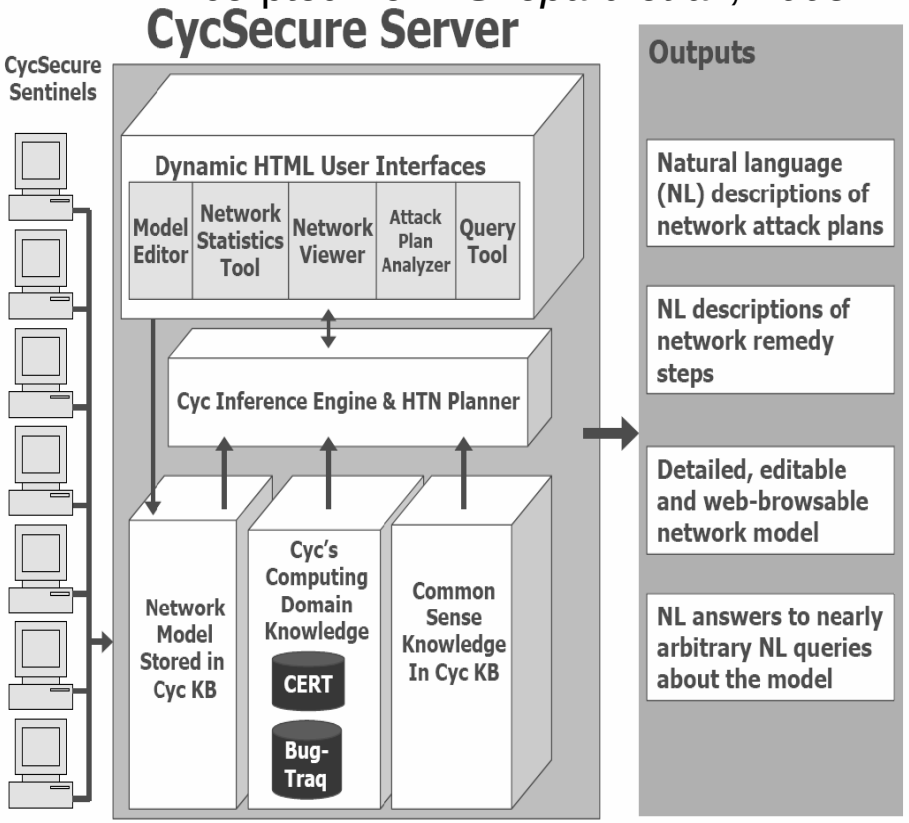
Software verification
(small to medium programs)

Much of recent progress based on:
Encodings into propositional satisfiability (SAT)

Logic: CycSecure

"**scans a computer network** to **build a formal representation** of the network, based on Cyc's pre-existing ontology of networking, security, and computing concepts:

Excerpted from: *Shepard et al., 2005*



This formal representation also allows users to interact directly with the model of the network, allowing testing of proposed changes."

- **Knowledge Representation**
- **Web Mining & Semantic Web !**

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Representation
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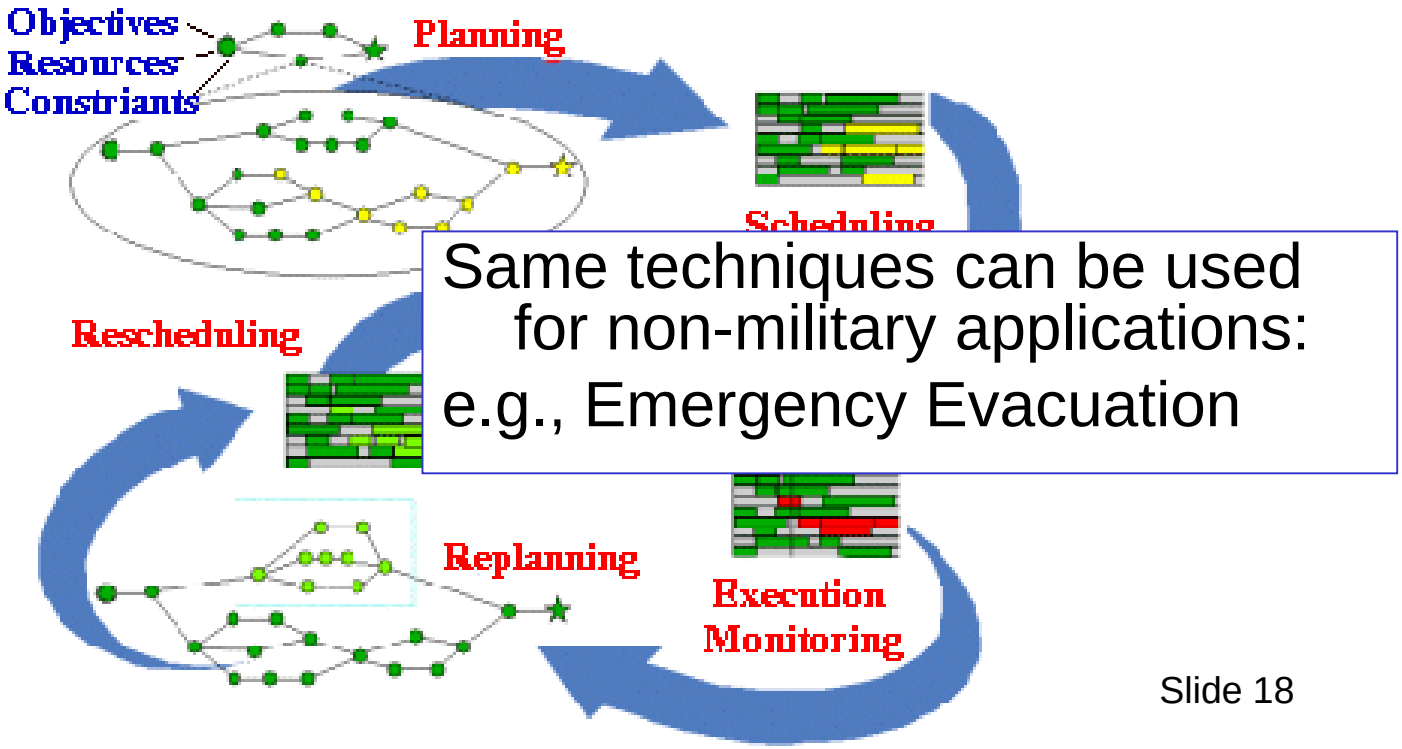
Planning & Scheduling: Logistics

Dynamic Analysis and Replanning Tool (Cross & Walker)

- logistics planning and scheduling for military transport
- used in the 1991 Gulf War by the US
- problems had 50,000 entities (e.g., vehicles); different starting points and destinations

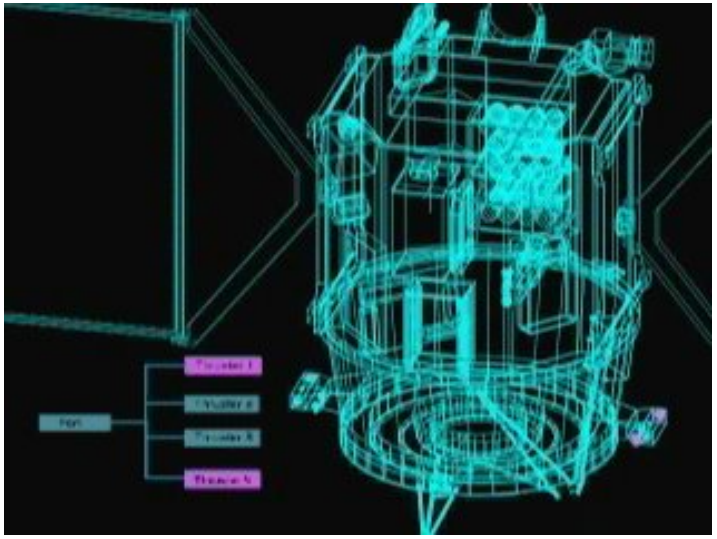


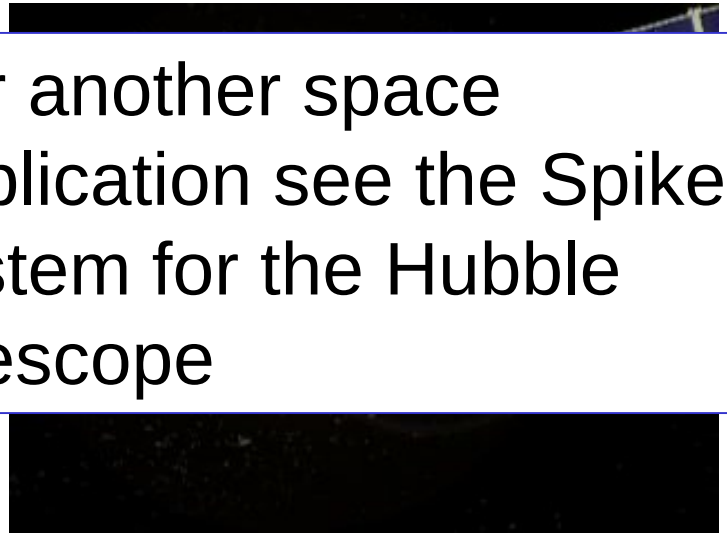
Source: *DARPA*

Planning: Spacecraft Control

NASA: Deep Space One spacecraft operated autonomously for two days in May, 1999:

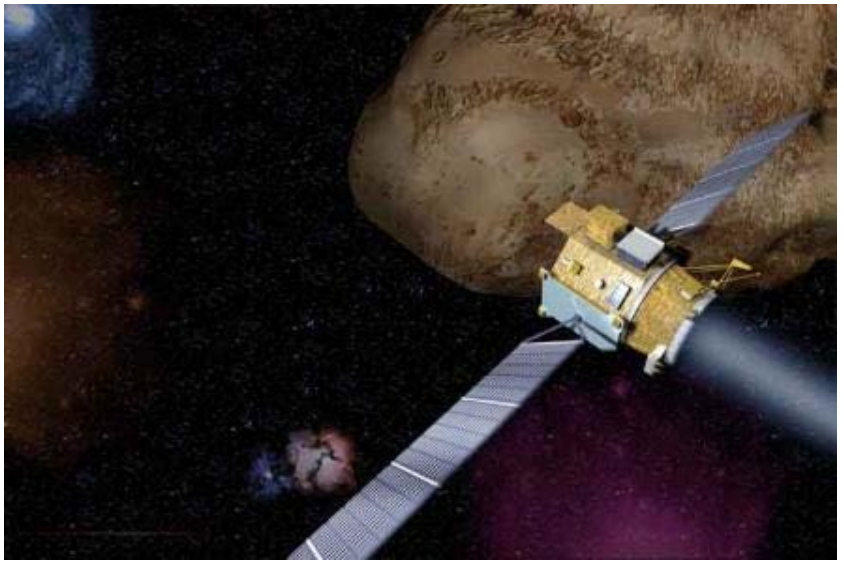
- determined its precise position using stars and asteriods
  - ✓despite a malfunctioning ultraviolet detector
- planned the necessary course adjustment
- fired the ion propulsion system to make this adjustment

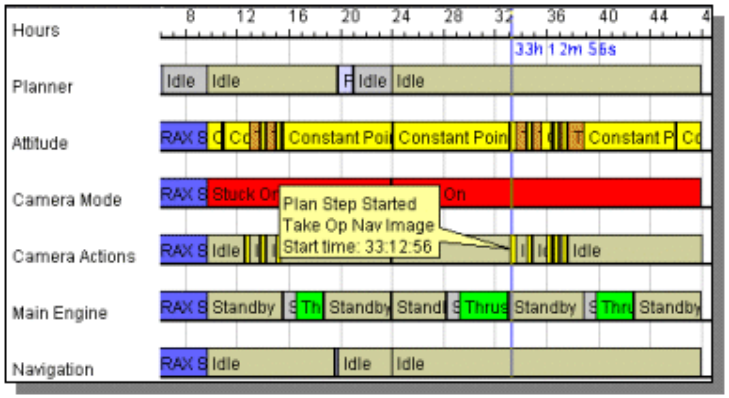


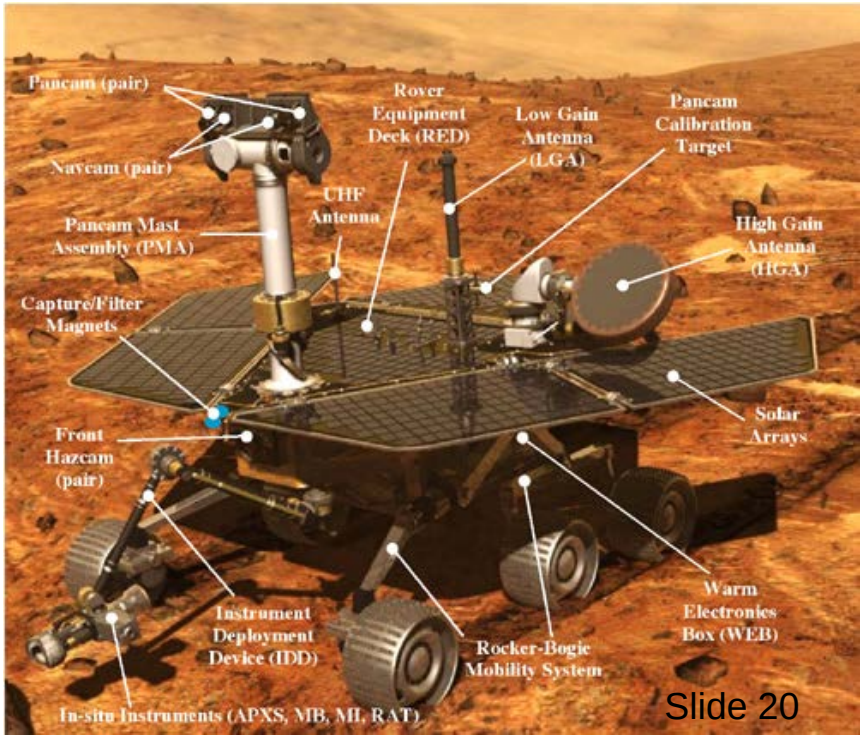


For another space application see the Spike system for the Hubble telescope

Source: *NASA*







Source:
cs221 stanford

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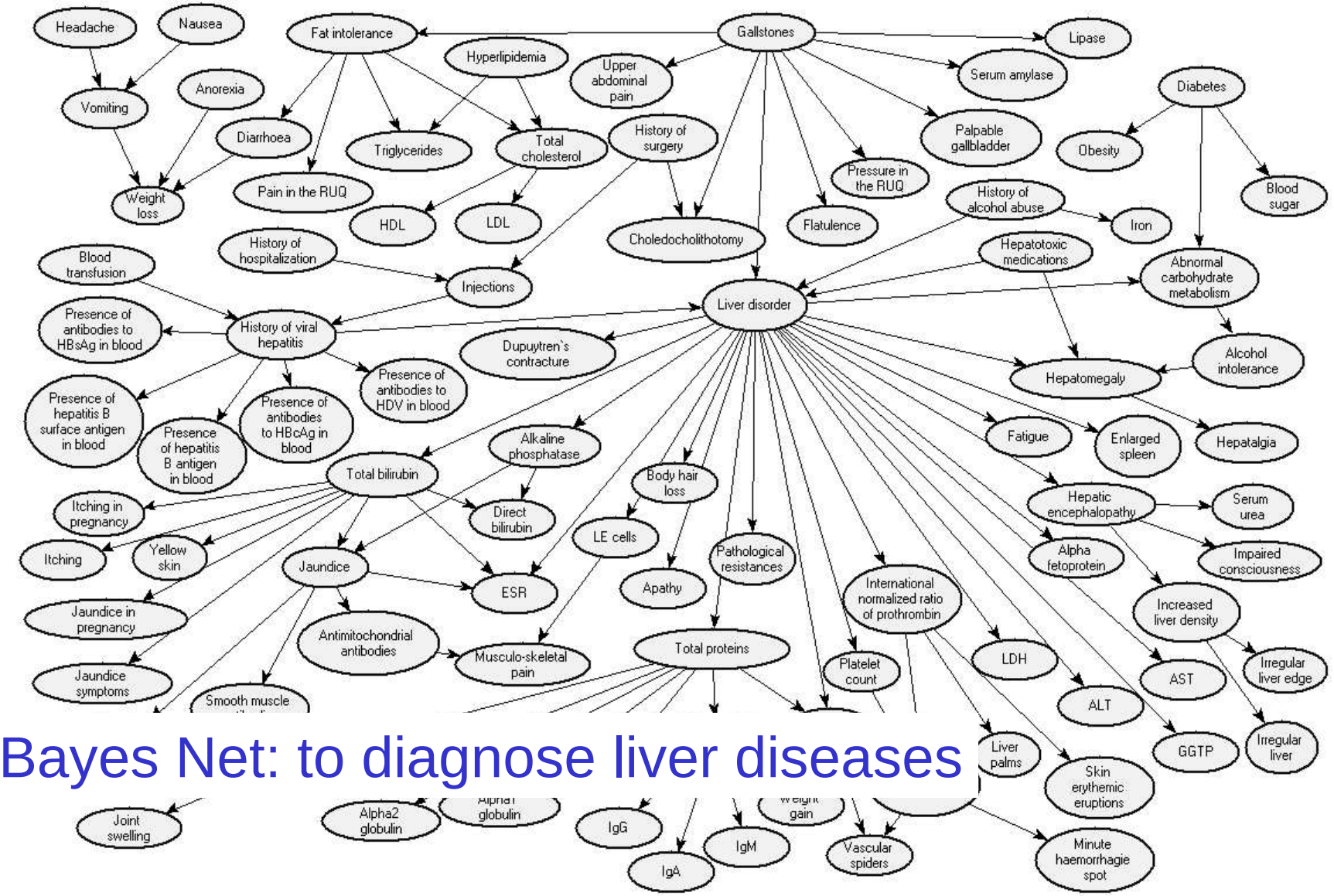
Representation
Reasoning Technique

Reasoning under Uncertainty: Diagnosis



Bayes Net: to diagnose liver diseases

Source: *Onisko et al., 99*

Reasoning Under Uncertainty

Texture classification using Support Vector Machines

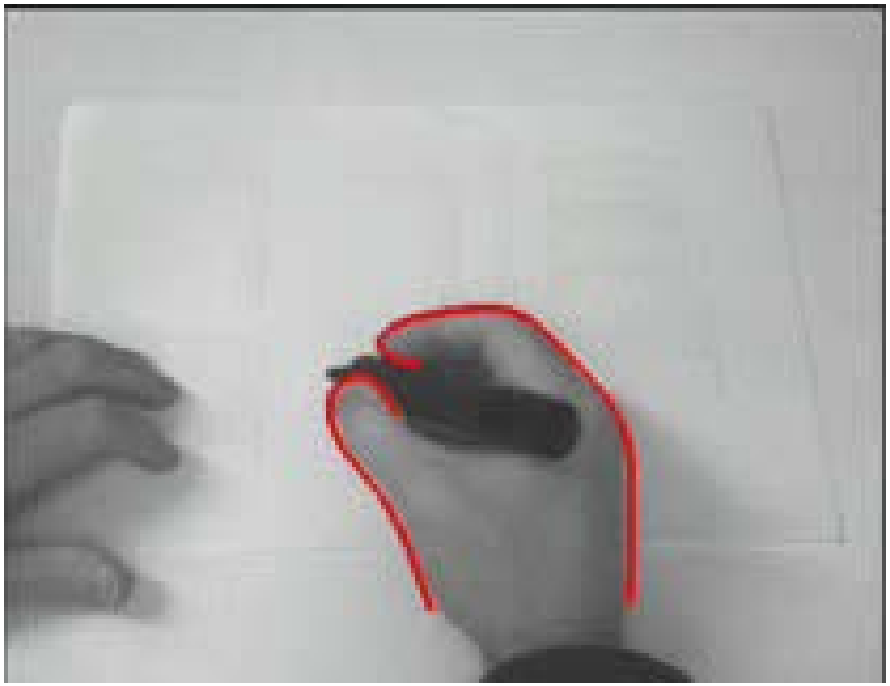
- foliage, building, sky, water

Source: *Mike Cora, UBC*

Reasoning Under Uncertainty

E.g. motion tracking: track a hand and estimate activity:

- drawing, erasing/shading, other



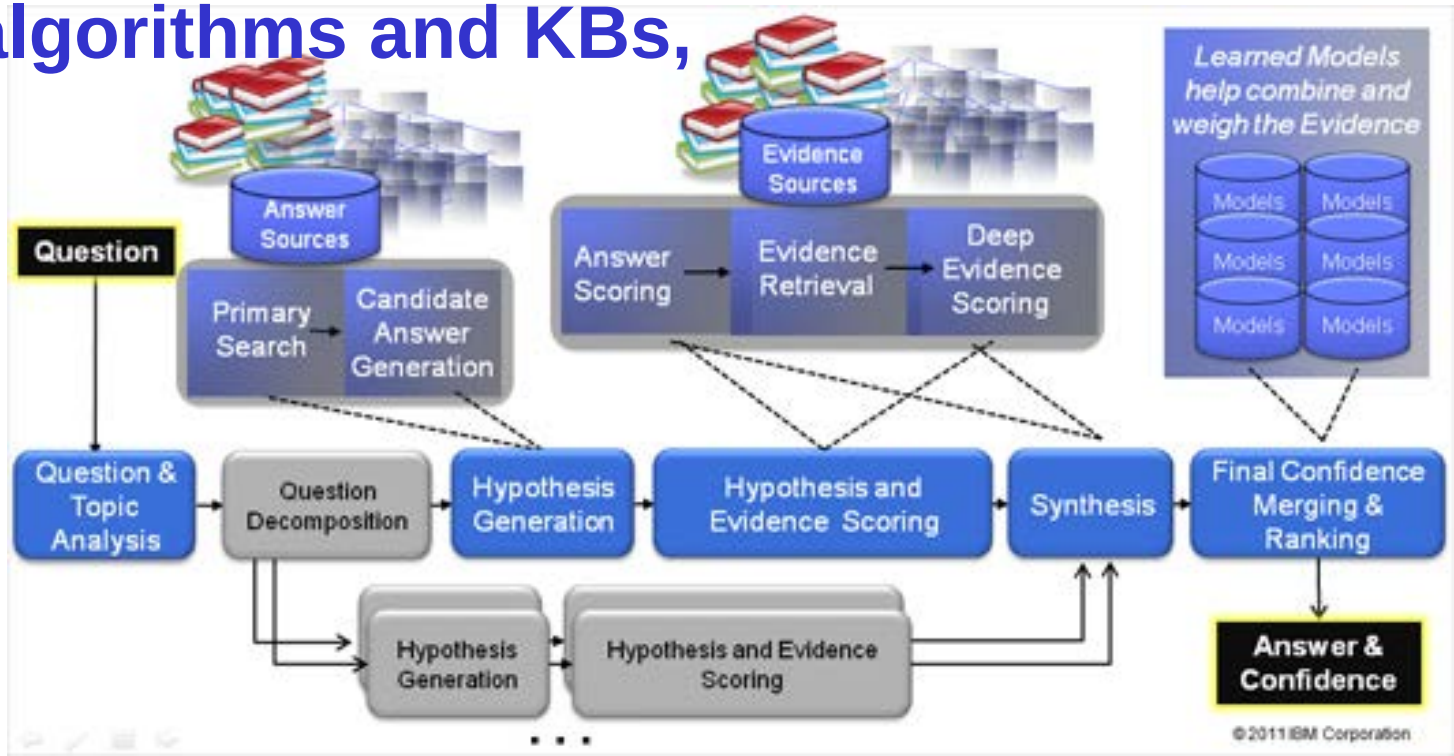
Source:
Kevin Murphy,
UBC

JEOPARDY! The IBM Challenge

Watson : analyzes natural language questions and content well enough and fast enough to compete and win against champion players at Jeopardy!

"This Drug has been shown to relieve the symptoms of ADD with relatively few side effects."

- **3 secs**
- **1000s of algorithms and KBs,**



Source:
IBM

Statistical Machine Translation

SEHR GEEHRTER GAST!
KUNST, KULTUR UND
KOMFORT IM HERZEN
BERLIN.

DEAR GUESTS,
ART, CULTURE AND
LUXURY IN THE HEART
OF BERLIN.

DIE ÖRTLICHE
NETZSPANNUNG BETRÄGT
220/240 VOLT BEI 50 HERTZ.

THE LOCAL VOLTAGE
IS 220/240 VOLTS 50 HZ.

DE

EN

Source:
cs221 Stanford

Recommender Systems

Suggesting new content/products based on what you have already viewed/consumed

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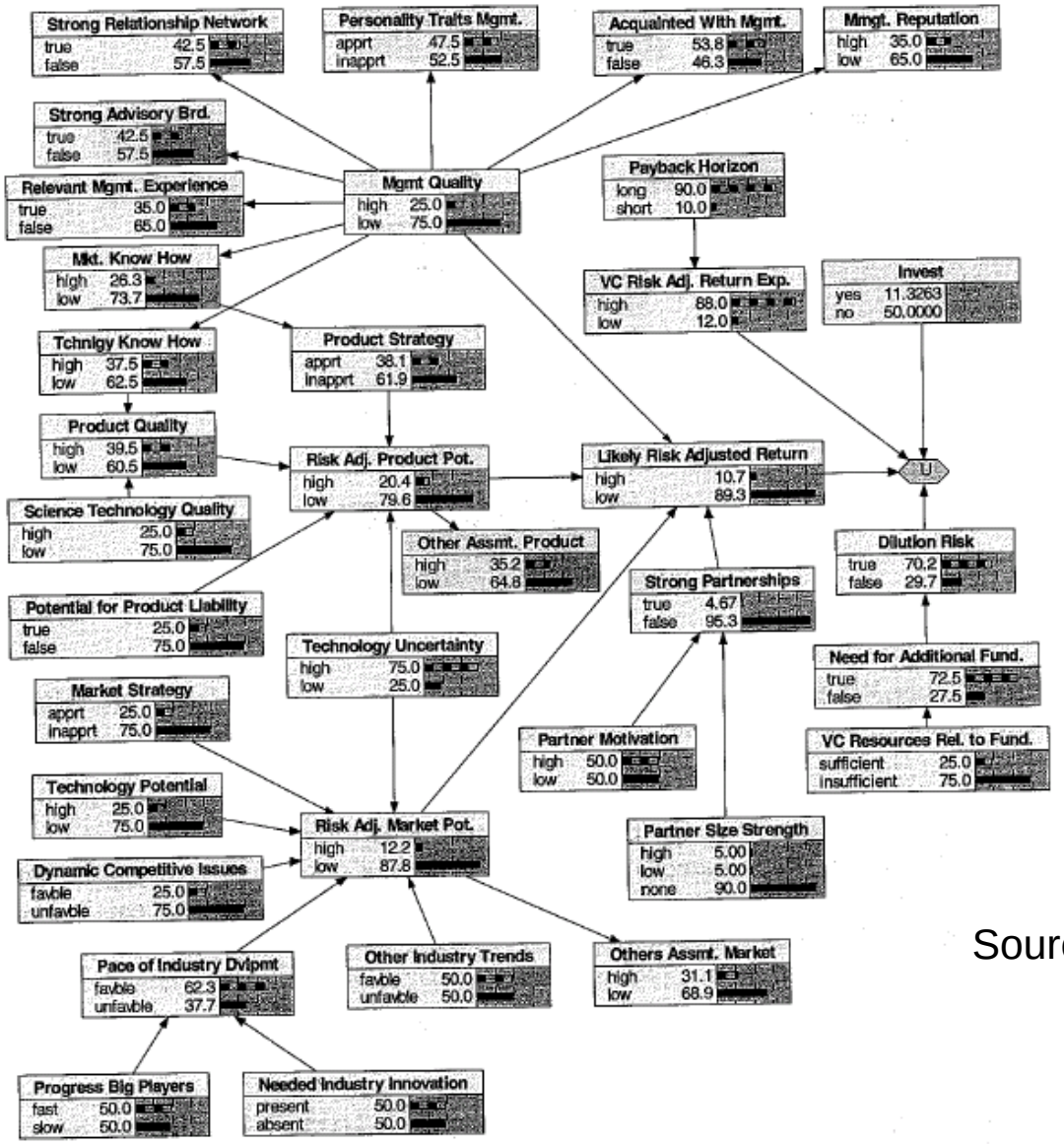
Decision Network in Finance for venture capital decision



Source: *R.E. Neapolitan, 2007*

Planning Under Uncertainty

Learning and Using PO**MDP** models of Patient-Caregiver Interactions During Activities of Daily Living

Goal: Help Older adults living with cognitive disabilities (such as Alzheimer's) when they:

- **forget the proper sequence of tasks** that need to be completed
- **they lose track of the steps** that they have already completed.

Source: *Jesse Hoey UofT 2007*

Military applications: ethical issues

- Robot soldiers
  - Existing: robot dog carrying heavy
    materials for soldiers in the field
  - The technology is there
- Unmanned airplanes
- Missile tracking
- Surveillance
- …

Decision Theory: Decision Support Systems

E.g., Computational Sustainability

Interdisciplinary field, AI is a key component

- Models and methods for decision making concerning the management and allocation of resources
- to solve most challenging problems related to sustainability

Often constraint optimization problems. E.g.

- Energy: when are where to produce green energy most economically?
- Which parcels of land to purchase to protect endangered species?
- Urban planning: how to use budget for best development in 30 years?

Source: http://www.computational-sustainability.org/

Dimensions of Representational Complexity in CPSC322

We've already discussed:

- Deterministic versus stochastic domains
- Static versus sequential domains

Some other important dimensions of complexity:

- Explicit state or propositions or relations
- Flat or hierarchical
- Knowledge given versus knowledge learned from experience
- Goals versus complex preferences
- Single-agent vs. multi-agent

Multiagent Systems: Poker

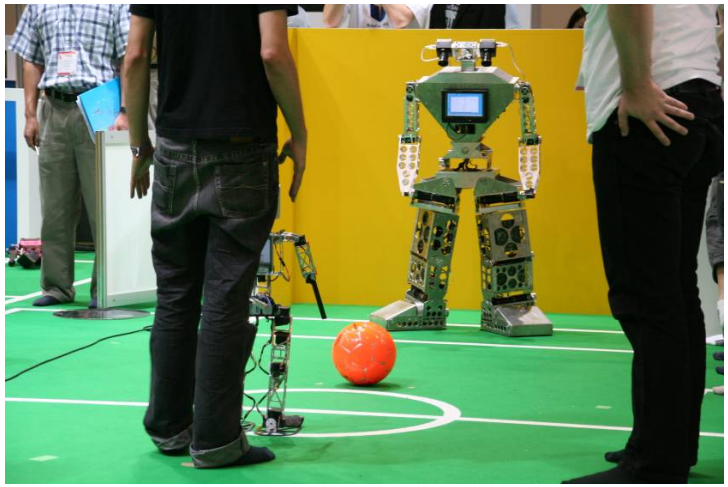
Search Space: 1.2 quintillion nodes

"In full 10-player games Poki is **better than a typical low-limit casino player** and wins consistently; however, **not as good as most experts**

New programs being developed for the 2-player game are quite a bit better, and we believe they will very soon surpass all human players"

Source: *The University of Alberta GAMES Group*

Multiagent Systems: Robot Soccer



Extremely complex

- Stochastic
- Sequence of actions
- Multiagent

robotic soccer competition was proposed by LCI (UBC) in 1992 (which became *Robocup* in 1997).

Source: *RoboCup web site*