Artificial Intelligence

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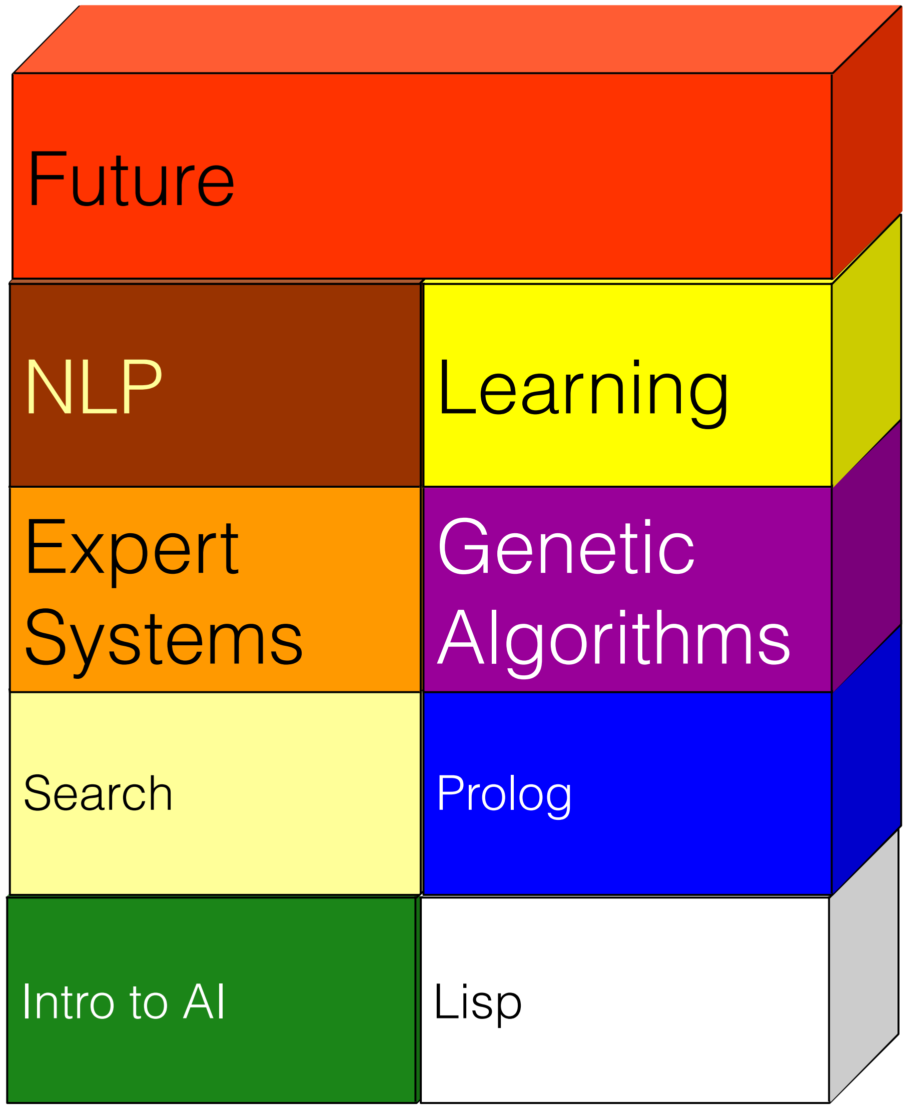
Course Objectives

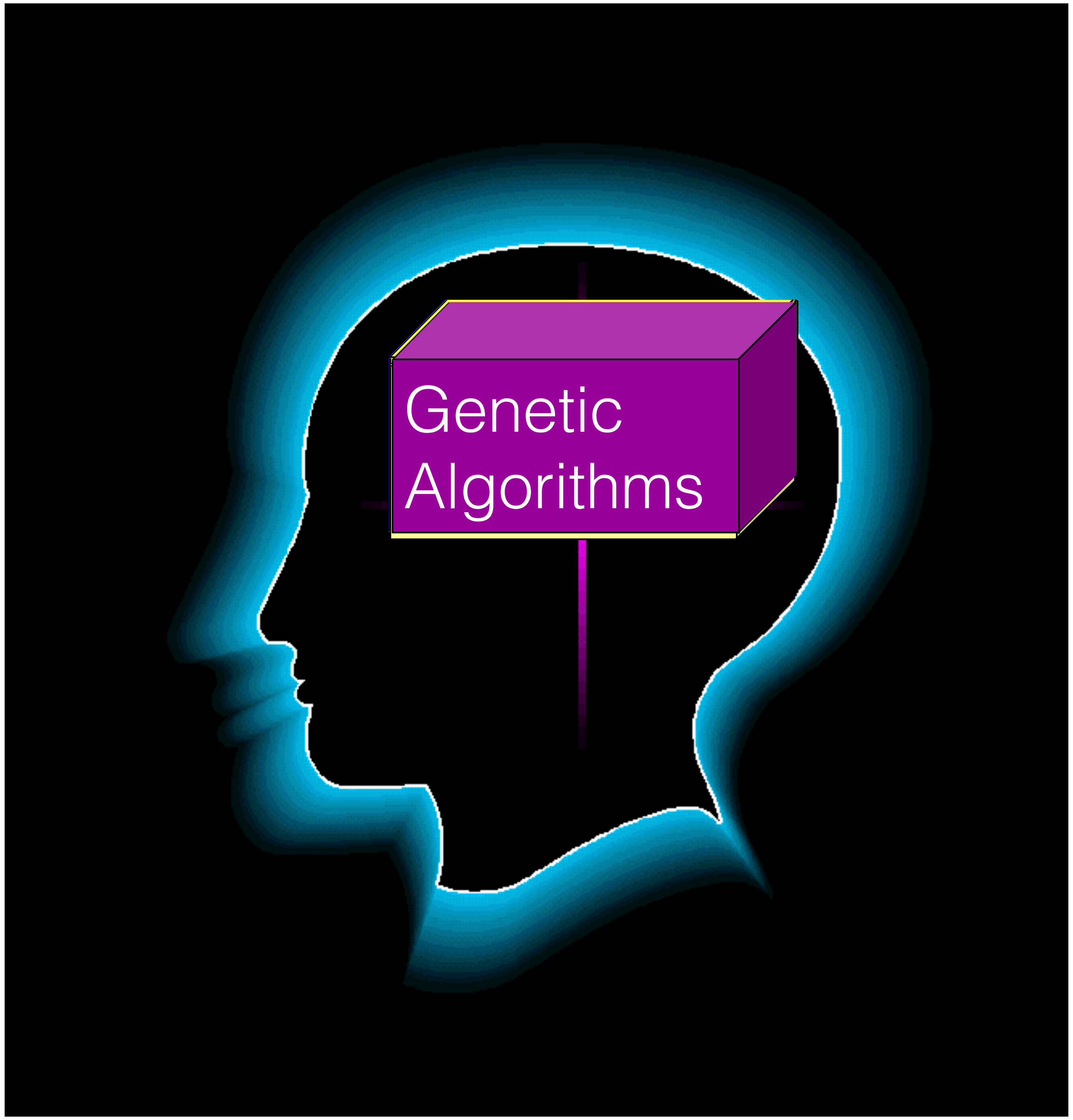
- To provide basic knowledge of Artificial Intelligence

- To familiarize students with different search techniques

- To acquaint students with the fields related to AI and the applications of AI

Course Contents





Syllabus

1. *Introduction to AI*
2. *Problem solving*
3. *Search techniques*
4. *Knowledge representation, inference and reasoning*
5. *Structured knowledge representation*
6. *Machine learning*
7. *Applications of AI*

References

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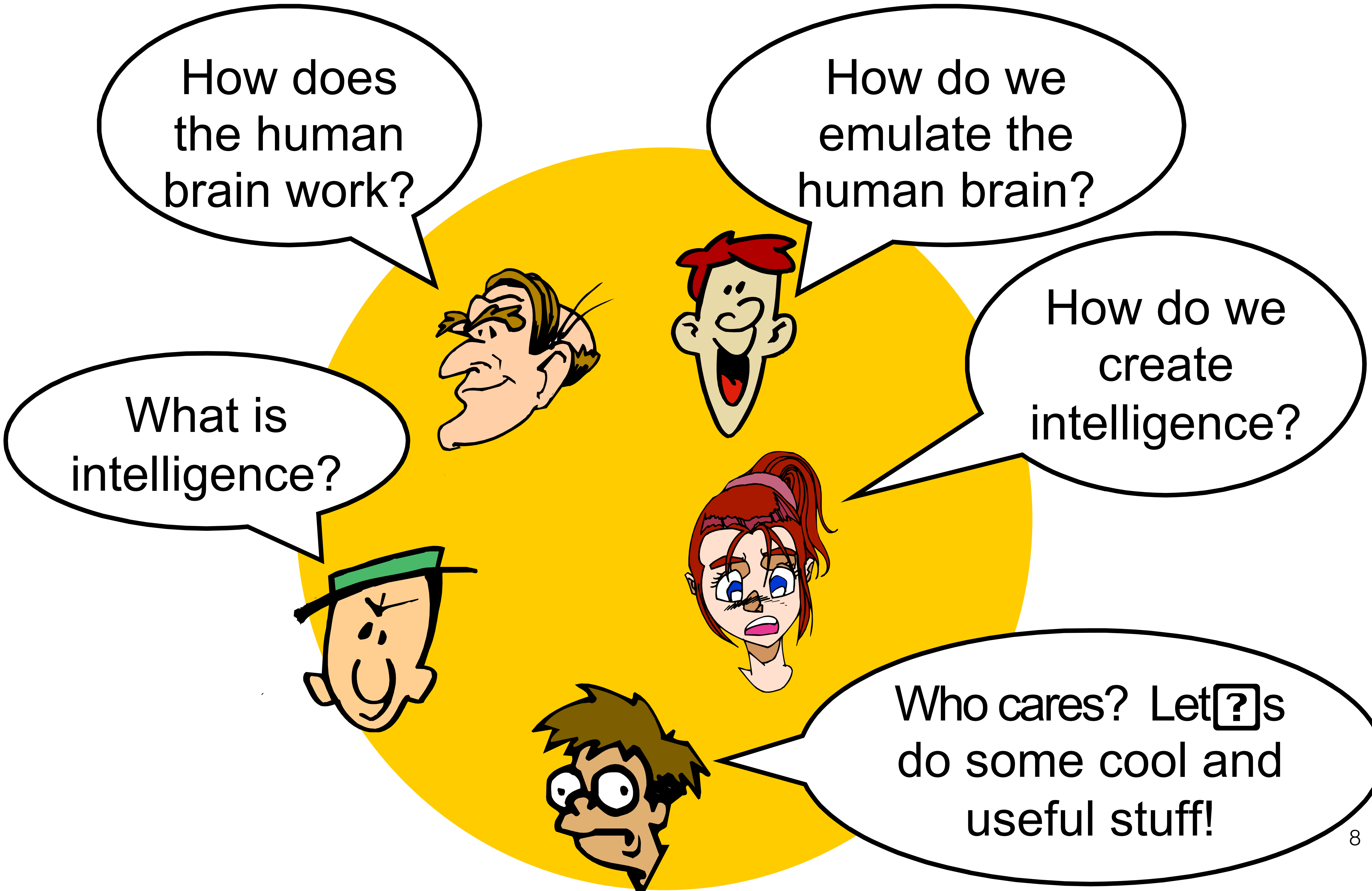
An Introduction to AI

What is AI?


How does the human brain work?
How do we emulate the human brain?
How do we create intelligence?
What is intelligence?
Who cares? Let?s do some cool and useful stuff!

Meaning of the word: ``intelligence''

1 *(a)* ***The capacity to acquire and apply knowledge***.

(b) ***The faculty of thought and reason.***

(c) ***Superior powers of mind.*** See Synonyms at mind.

2 An intelligent, incorporeal being, especially an angel.

3 Information; news. See Synonyms at news.

4 (a) Secret information, especially about an actual or potential enemy.

(b) An agency, staff, or office employed in gathering such information.

(c) Espionage agents, organizations, and activities considered as a group

Source: The American Heritage® Dictionary of the English Language, Fourth Edition

Meaning of the word: ``intelligence''

n

1: ***the ability to comprehend; to understand and profit from experience***
[ant: stupidity]

2: a unit responsible for gathering and interpreting intelligence

3: secret information about an enemy (or potential enemy); "we sent out planes to gather intelligence on their radar coverage"

4: new information about specific and timely events; "they awaited news of the outcome" [syn: news, tidings, word]

5: the operation of gathering information about an enemy [syn: intelligence activity, intelligence operation]

Source: WordNet ® 1.6, © 1997 Princeton University

What Behaviors are Intelligent?

Everyday tasks: recognize a friend, recognize who is calling, translate from one language to another, interpret a photograph, talk, cook a dinner

Formal tasks: prove a logic theorem, geometry, calculus, play chess, checkers, or Go

Expert tasks: engineering design, medical designers, financial analysis

Artificial Intelligence

Based on the above, `artificial intelligence' is about the science and engineering necessary to create artifacts that can

- acquire knowledge, i.e., can learn and extract knowledge; and
- reason with knowledge (leading to doing tasks such as planning, explaining, diagnosing, acting rationally, etc.),

Formal Definitions

Barr and Feigenbaum

"Artificial Intelligence is the part of computer science concerned with designing intelligence computer systems, that is, systems that exhibit the characteristics we associate with intelligence in human behavior."

Elaine Rich

"AI is the study of how to make computers do things at which, at the moment, people are better"

Different Types of Artificial Intelligence

- **Modeling exactly how humans actually think**
  - cognitive models of human reasoning

- **Modeling exactly how humans actually act**
  - models of human behavior (what they do, not how they think)

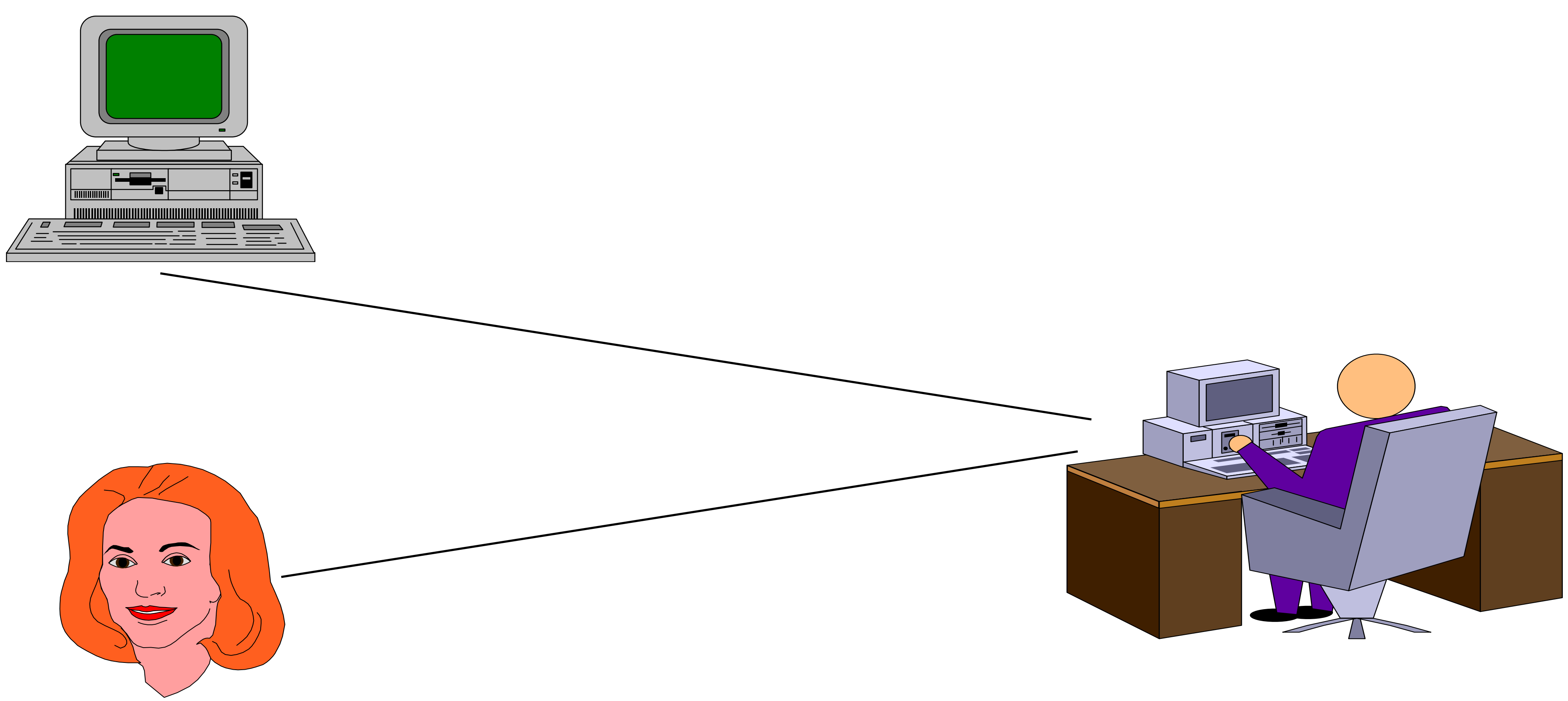
- **Modeling how ideal agents "should think"**
  - models of "rational" thought (formal logic)
  - note: humans are often not rational!

- **Modeling how ideal agents "should act"**
  - rational actions but not necessarily formal rational reasoning
  - i.e., more of a black-box/engineering approach

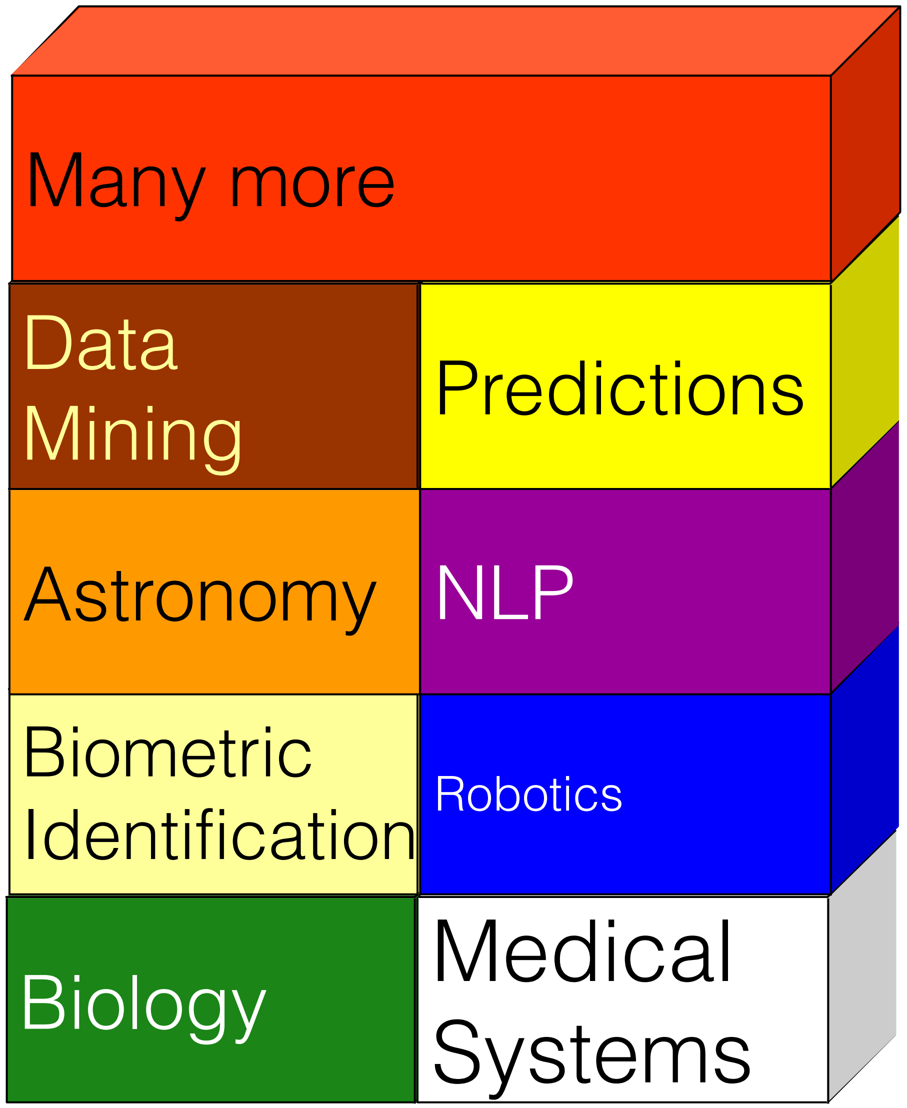
- **Modern AI focuses on the last definition**
  - we will also focus on this "engineering" approach
  - success is judged by how well the agent perform
  - -- modern methods are inspired by cognitive & neuroscience (how people think).

Acting humanly: Turing Test

- Turing (1950) "Computing machinery and intelligence":
- "Can machines think?" → "Can machines behave intelligently?"
- Operational test for intelligent behavior: the Imitation Game
  - The interrogator can communicate two with sources: one is human and the other is a machine
  - He must decide which is which
  - If he is wrong half the time, then the machine is intelligent



AI Today


Many more
Data Mining
Predictions
Astronomy
NLP
Biometric Identification
Robotics
Biology
Medical Systems

AI Today

- *Diagnose lymph- node diseases* [Heckerman, 91]
- *Monitor space shuttle missions* [Horvitz, 92]
- *Automatic vehicle control* [Jochem et al., 96]
- *Large- scale scheduling* [Smith et al., 96]
- *Classify astronomical objects* [Goebel et al., 89]
- *Automatic design and configuration systems*
- *First commercial speech understanding systems*
- *Beat world's best players in chess, checkers, and backgammon.*

Prolog

First Prolog program: France, 1970

- Based on theorem proving research
- Major development at University of Edinburgh, 1975-79
- Adopted by the Japanese Fifth Generation Computing Project

Logic programming language:

- Programs composed of facts and rules
- Executes by applying first-order predicate calculus/unification to programs
- Interactive interpreter, compiler
- Tell the computer what is true and what needs to be done, rather than how to do

```
likes(deb, Y) :- horse(Y).
horse(robin).
?-  likes(deb, robin).
yes
```

```
likes(deb, horses).
likes(deb, dogs).
?-  likes(deb, horses).
yes
?-  likes(deb, X).
X=horses
X=dogs
```

LISP

- Proposed by McCarthy, late 1950s; contemporary of COBOL, FORTRAN
- Functional programming language based on lambda calculus/recursive function theory
- Intended as a language for symbolic rather than numeric computation
- Interactive interpreter, compiler
- Uses atoms, lists, functions.

```
(defun hypotenuse (x y)
   (sqrt (+ (square x)
            (square y))))

> (hypotenuse 4 3)
5
```

History of AI

- 1943 McCulloch & Pitts: Boolean circuit model of brain
- 1950 Turing's "Computing Machinery and Intelligence"
- 1956 Dartmouth meeting: "Artificial Intelligence" adopted
- 1950s Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
- 1965 Robinson's complete algorithm for logical reasoning
- 1966—73 AI discovers computational complexity
  Neural network research almost disappears
- 1969—79 Early development of knowledge-based systems
- 1980-- AI becomes an industry
- 1986-- Neural networks return to popularity
- 1987-- AI becomes a science
- 1995-- The emergence of intelligent agents

Artificial Intelligence

- Common sense reasoning
- Reasoning under uncertain conditions
- Learning from experience
- Planning and executing complex tasks
- Understanding and communicating in spoken/written language
- Visual comprehension

Note: "easy for human" != "easy for machine".

Chess is easy for computer, hard for human.

Visual recognition of chess pieces is easy for human, hard for computer.

"Tasks that require knowledge of some domain"

Knowledge Definition

- “The fact or condition of *knowing something* with familiarity gained through experience or association.” (Webster’s Dictionary, 1988)(Knowing something via seeing, hearing, touching, feeling, and tasting.)

- “The fact or condition of *being aware of* something” . (Ex. Sun is hot, balls are round, sky is blue,…)

Knowledge Storing

Natural language for people

- **Symbols for computer: a number or character string that represents an object or idea (Internal representation of the knowledge).**
- **The core concepts: mapping from facts to an internal computer representation and also to a form that people can understand.**

Knowledge Representation

- Simple facts or complex relationships
- Mathematical formulas or rules for natural language syntax
- Associations between related concepts
- Inheritance hierarchies between classes of objects
- Knowledge is not a “one-size-fits-all” proposition.

Knowledge

Example: automated language translation (English <-----> Japanese)

”My name is hari bahadur."
”Madan bahadur is my friend."

Must determine what this means using knowledge of human discourse in English

word-by-word
translation
--------------------->

Then generate japanese form of that meaning

Knowledge

Note: *knowledge != data.*

Example: determining voltage from current and resistance

Data	Knowledge
V=12, I=6, R=2 V=28, I=4, R=7 V=9, I=3, R=3 V=12, I=3, R=4 V=15, I=3, R=5	V = I * R

- Knowledge is *more compact* and *faster to manipulate.*
- Knowledge is *more general* (that is, may be applied to situations we have *not* been programmed for).
- Important feature of intelligence: *creating knowledge* from data.

Knowledge

"Heuristics for making good decisions when no algorithm exists for doing so"

That is, for many of the above problem, we must often make *intelligent guesses* due to:

- Lack of *complete knowledge* about how to solve problem.
- Lack of *complete data* about current situation.
- Lack of *time* to completely explore situation.

Example: walking across room.

Do not have complete knowledge of physical laws associated with motion.

Do not have complete knowledge of room (such as what might be behind objects).

Do not have time to map out and compare all possible paths through room.

What is Learning?

Learning is one of those everyday terms which is broadly and vaguely used in the English language

- **Learning is making useful changes in our minds**
- **Learning is constructing or modifying representations of what is being experienced**
- **Learning is the phenomenon of knowledge acquisition in the absence of explicit programming**

Herbert Simon, 1983

Learning denotes changes in the system that are adaptive in the sense that they enable the system to do the same task or tasks drawn from the same population more efficiently and more effectively next time.

What is Learning?

Learning involves 3 factors:

changes

generalization

improvement

Learning changes the learner: for machine learning the problem is determining the nature of these changes and how to best represent them

Learning leads to generalization: performance must improve not only on the same task but on similar tasks

Learning leads to improvements: machine learning must address the possibility that changes may degrade performance and find ways to prevent it.

Consider what might be involved in building a "intelligent" computer….

- *What are the* **"***components***"** *that might be useful?*
  - Fast hardware?
  - Foolproof software?
  - Chess-playing at grandmaster level?
  - Speech interaction?

    speech synthesis

    speech recognition

    speech understanding
  - Image recognition and understanding ?
  - Learning?
  - Planning and decision-making?

Can we build hardware as complex as the brain?

- *How complicated is our brain?*
  - a neuron, or nerve cell, is the basic information processing unit
  - estimated to be on the order of 10^{11} neurons in a human brain
  - many more synapses (10^{14}) connecting these neurons
  - cycle time: 10^{-3} seconds (1 millisecond)

- *How complex can we make computers?*
  - 10^{6} or more transistors per CPU
  - supercomputer: hundreds of CPUs, 10^{9} bits of RAM
  - cycle times: order of 10^{-8} seconds

- *Conclusion*
  - *YES*: in the near future we can have computers with as many basic processing elements as our brain, but with
    - far fewer interconnections (wires or synapses) than the brain
    - much faster updates than the brain
  - *but* building hardware is very different from making a computer behave like a brain!

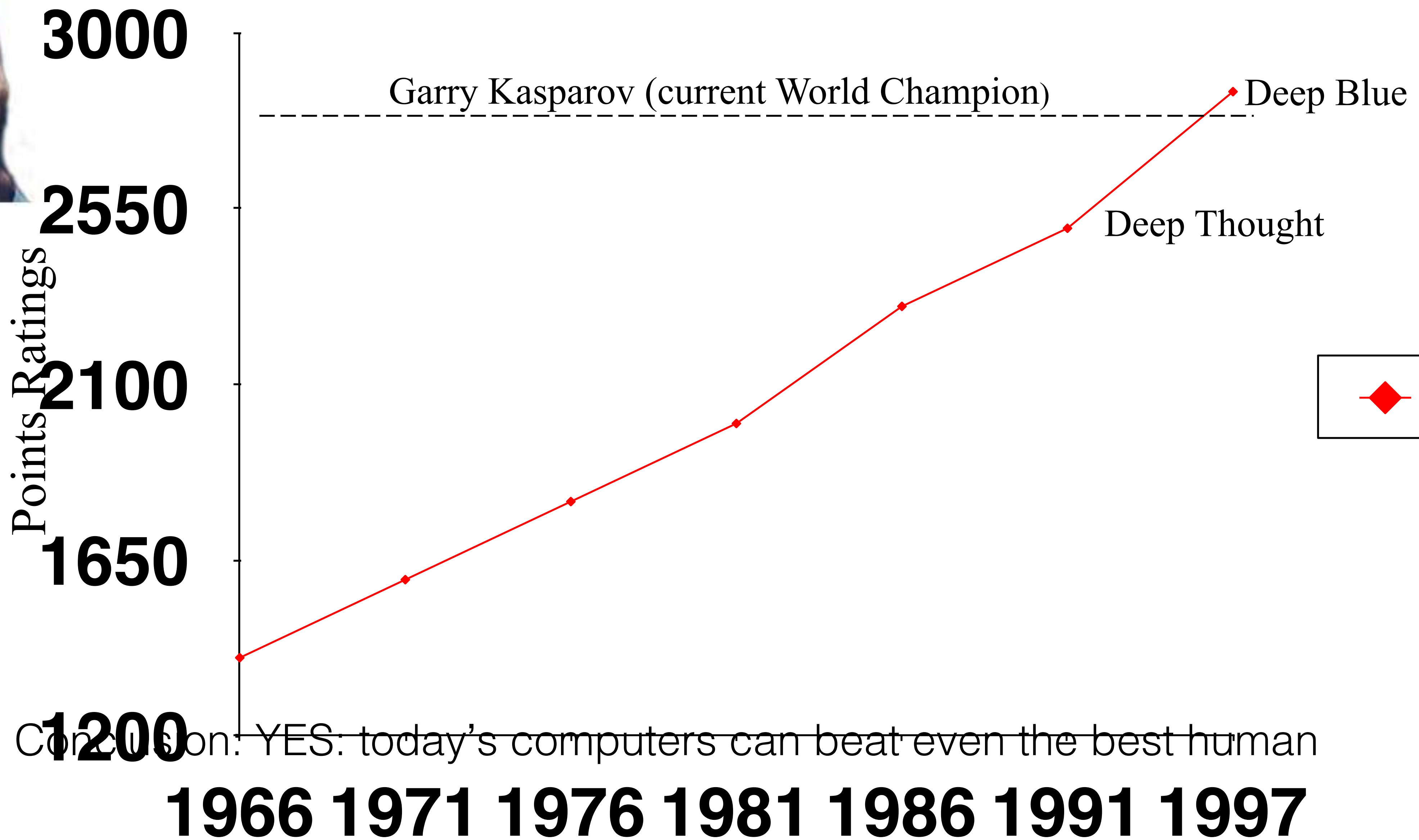
Must an Intelligent System be Foolproof?

- *A “foolproof” system is one that never makes an error:*
  - Types of possible computer errors
    - hardware errors, e.g., memory errors
    - software errors, e.g., coding bugs
    - “human-like” errors
  - Clearly, hardware and software errors are possible in practice
  - what about “human-like” errors?

- *An intelligent system can make errors and still be intelligent*
  - humans are not right all of the time
  - we learn and adapt from making mistakes
    - e.g., consider learning to surf or ski
      - we improve by taking risks and falling
      - an intelligent system can learn in the same way
- *Conclusion:*
  - *NO*: intelligent systems will not (and need not) be foolproof

Can Computers play Humans at Chess?

- *Chess Playing is a classic AI problem*
  - well-defined problem
  - very complex: difficult for humans to play well



- Conclusion: YES: today's computers can beat even the best human

Can Computers Talk?

- *This is known as* **“***speech synthesis*”
  - translate text to phonetic form

    e.g., “fictitious” -> fik-tish-es
  - use pronunciation rules to map phonemes to actual sound

    e.g., “tish” -> sequence of basic audio sounds

- *Difficulties*
  - sounds made by this “lookup” approach sound unnatural
  - sounds are not independent

    e.g., “act” and “action”

    modern systems (e.g., at AT&T) can handle this pretty well
  - a harder problem is emphasis, emotion, etc

    humans understand what they are saying

    machines don’t: so they sound unnatural

- *Conclusion: NO,* for complete sentences, but YES for individual words

Can Computers Recognize Speech?

- *Speech Recognition*:
  - mapping sounds from a microphone into a list of words.
  - Hard problem: noise, more than one person talking,

    occlusion, speech variability,..
  - Even if we recognize each word, we may not understand its meaning.

- *Recognizing single words from a small vocabulary*

  systems can do this with high accuracy (order of 99%)

  e.g., directory inquiries

  limited vocabulary (area codes, city names)

  computer tries to recognize you first, if unsuccessful hands you over to a human operator

  saves millions of dollars a year for the phone companies

Recognizing human speech (ctd.)

- *Recognizing normal speech is much more difficult*
  - speech is continuous: where are the boundaries between words?

    e.g., "John's car has a flat tire"
  - large vocabularies

    can be many thousands of possible words

    we can use *context* to help figure out what someone said

    try telling a waiter in a restaurant:
    "I would like some dream and sugar in my coffee"
  - background noise, other speakers, accents, colds, etc
  - on normal speech, modern systems are only about 60% accurate

- *Conclusion: NO*, normal speech is too complex to accurately recognize, but YES for restricted problems
  - (e.g., recent software for PC use by IBM, Dragon systems, etc)

Can Computers Understand speech?

- *Understanding is different to recognition:*
  - “Time flies like an arrow”

    assume the computer can recognize all the words

    but how could it understand it?

    1. time passes quickly like an arrow?
    2. command: time the flies the way an arrow times the flies
    3. command: only time those flies which are like an arrow
    4. “time-flies” are fond of arrows

    only 1. makes any sense, but how could a computer figure this out?

    clearly humans use a lot of implicit commonsense knowledge in communication

- *Conclusion: NO*, much of what we say is beyond the capabilities of a computer to understand at present

Can Computers Learn and Adapt ?

- *Learning and Adaptation*
  - consider a computer learning to drive on the freeway
  - we could code lots of rules about what to do
  - or we could let it drive and steer it back on course when it heads for the embankment

    systems like this are under development (e.g., Daimler Benz)

    e.g., RALPH at CMU

      in mid 90's it drove 98% of the way from Pittsburgh to San Diego without any human assistance

  - *machine learning* allows computers to learn to do things without explicit programming
- *Conclusion: YES*, computers can learn and adapt, when presented with information in the appropriate way

Can Computers “see”?

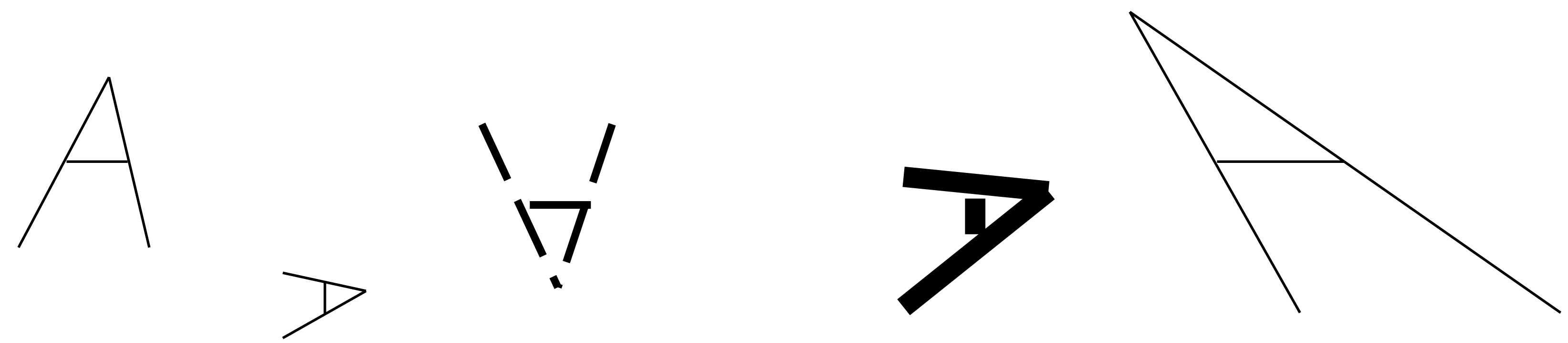
- *Recognition v. Understanding (like Speech)*
  - Recognition and Understanding of Objects in a scene

    look around this room

    you can effortlessly recognize objects

    human brain can map 2d visual image to 3d “map”

- *Why is visual recognition a hard problem?*



- *Conclusion: mostly NO*: computers can only “see” certain types of objects under limited circumstances: but *YES* for certain constrained problems (e.g., face recognition)

Can Computers plan and make decisions?

- *Intelligence*
  - involves solving problems and making decisions and plans
  - e.g., you want to visit your cousin in Boston

    you need to decide on dates, flights

    you need to get to the airport, etc

    involves a sequence of decisions, plans, and actions

- *What makes planning hard?*
  - the world is not predictable:

    your flight is canceled or there's a backup on the 405
  - there is a potentially huge number of details

    do you consider all flights? all dates?

    no: commonsense constrains your solutions
  - AI systems are only successful in constrained planning problems

- *Conclusion: NO*, real-world planning and decision-making is still beyond the capabilities of modern computers
  - exception: very well-defined, constrained problems: mission planning for satelites.

Academic Disciplines important to AI.

- **Philosophy** Logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality.
- **Mathematics** Formal representation and proof, algorithms, computation, (un)decidability, (in)tractability, probability.
- **Economics** utility, decision theory, rational economic agents
- **Neuroscience** neurons as information processing units.
- **Psychology/** how do people behave, perceive, process Cognitive Science information, represent knowledge.
- **Computer building fast computers engineering**
- **Control theory** design systems that maximize an objective function over time
- **Linguistics** knowledge representation, grammar

Intelligent Systems in Your Everyday Life

- *Post Office*
  - automatic address recognition and sorting of mail
- *Banks*
  - automatic check readers, signature verification systems
  - automated loan application classification
- *Telephone Companies*
  - automatic voice recognition for directory inquiries
  - automatic fraud detection,
- *Credit Card Companies*
  - automated fraud detection
- *Computer Companies*
  - automated diagnosis for help-desk applications
- *Recommendation systems*
  - *Product recommendation based on history*

AI Applications: Consumer Marketing

- Have you ever used any kind of credit/ATM/store card while shopping?
    - if so, you have very likely been “input” to an AI algorithm
- All of this information is recorded digitally
- Companies like Nielsen gather this information weekly and search for patterns
    - general changes in consumer behavior
    - tracking responses to new products
    - identifying customer segments: targeted marketing, e.g., they find out that consumers with sports cars who buy textbooks respond well to offers of new credit cards.
    - Currently a very hot area in marketing
- *How do they do this?*
    - Algorithms (“data mining”) search data for patterns
    - based on mathematical theories of learning
    - completely impractical to do manually

AI Applications: Identification Technologies

- *ID cards*
  - e.g., ATM cards
  - can be a nuisance and security risk:

    cards can be lost, stolen, passwords forgotten, etc
- *Biometric Identification*
  - walk up to a locked door

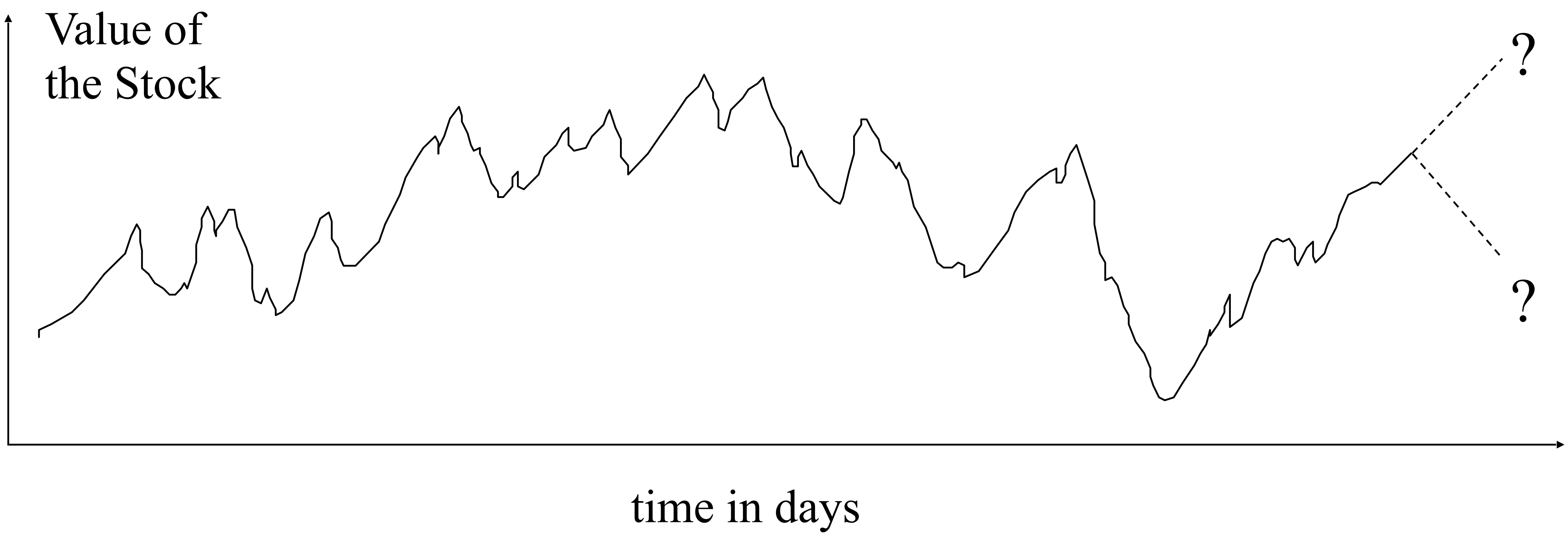
    camera

    fingerprint device

    microphone
  - computer uses your biometric signature for identification

    face, eyes, fingerprints, voice pattern

AI Applications: Predicting the Stock Market



- *The Prediction Problem*
  - given the past, predict the future
  - very difficult problem!
  - we can use learning algorithms to learn a predictive model from historical data

    `prob(increase at day t+1 | values at day t, t-1,t-2....,t-k)`
  - such models are routinely used by banks and financial traders to manage portfolios worth millions of dollars

AI-Applications: Machine Translation

- Language problems in international business
  - e.g., at a meeting of Japanese, Korean, Vietnamese and Swedish investors, no common language
  - or: you are shipping your software manuals to 127 countries
  - solution; hire translators to translate
  - would be much cheaper if a machine could do this!

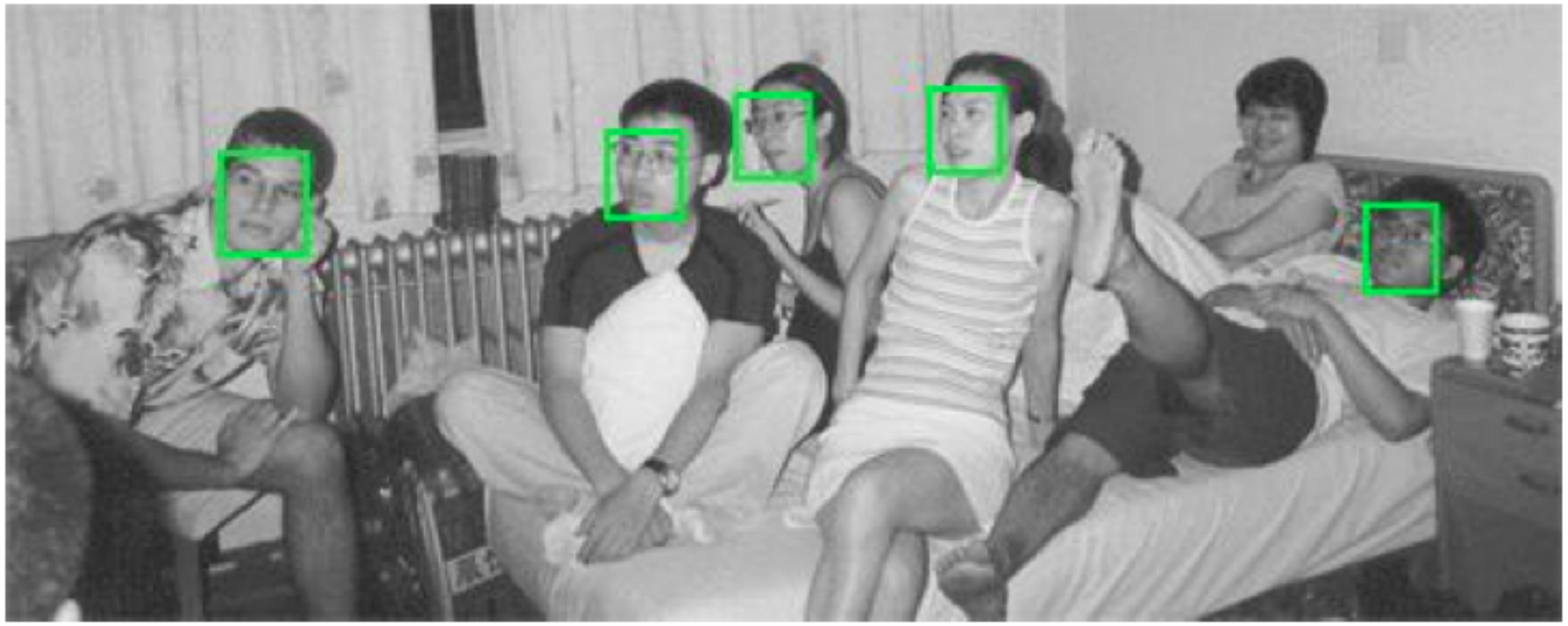
- How hard is automated translation
  - very difficult!
  - e.g., English to Russian

    "The spirit is willing but the flesh is weak" (English)

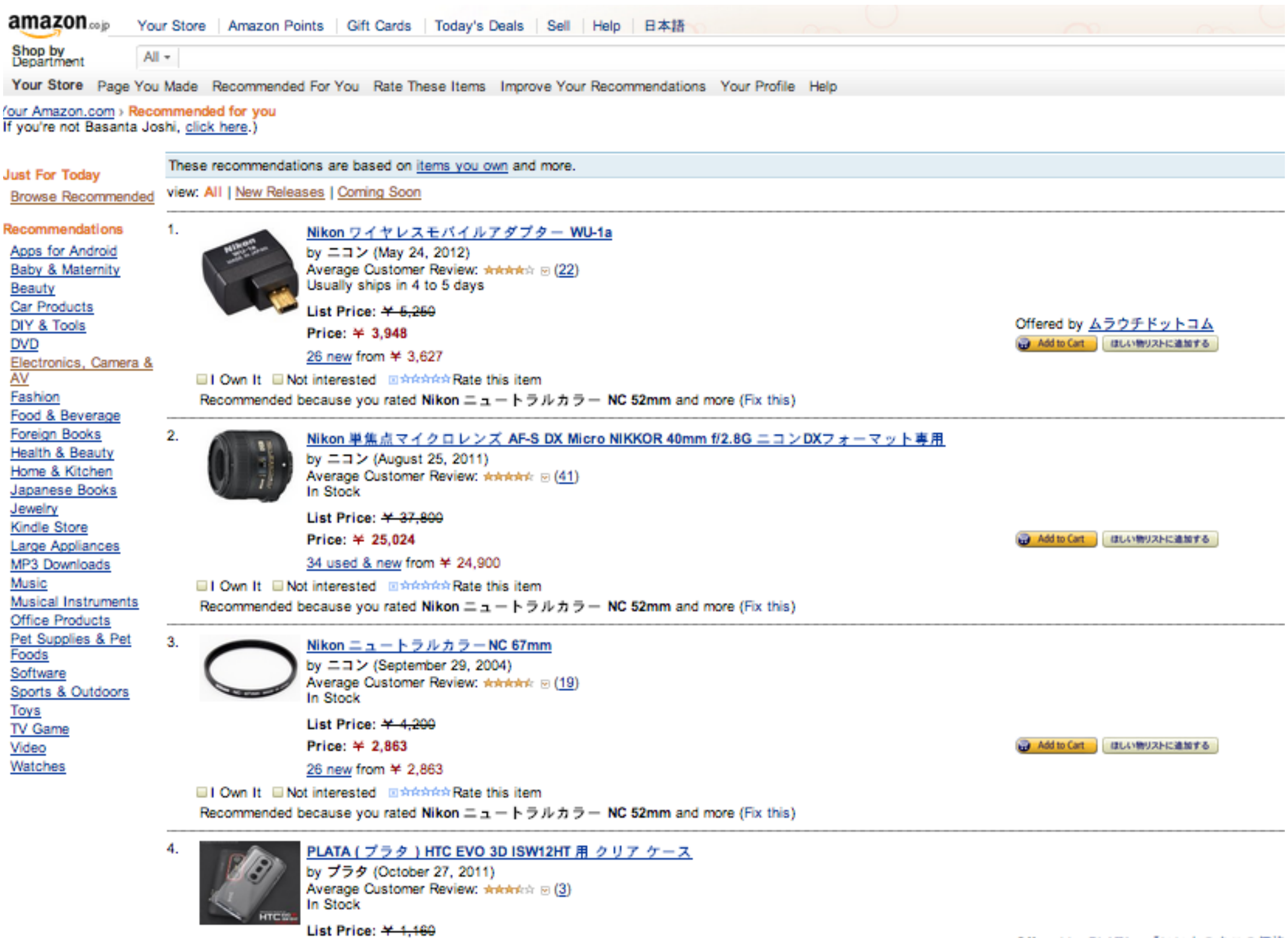
    "the vodka is good but the meat is rotten" (Russian)
  - not only must the words be translated, but their meaning also!

- Nonetheless....
  - commercial systems can do alot of the work very well (e.g.,restricted vocabularies in software documentation)
  - algorithms which combine dictionaries, grammar models, etc.
  - see for example babelfish.altavista.com

AI-Applications: Face Detection

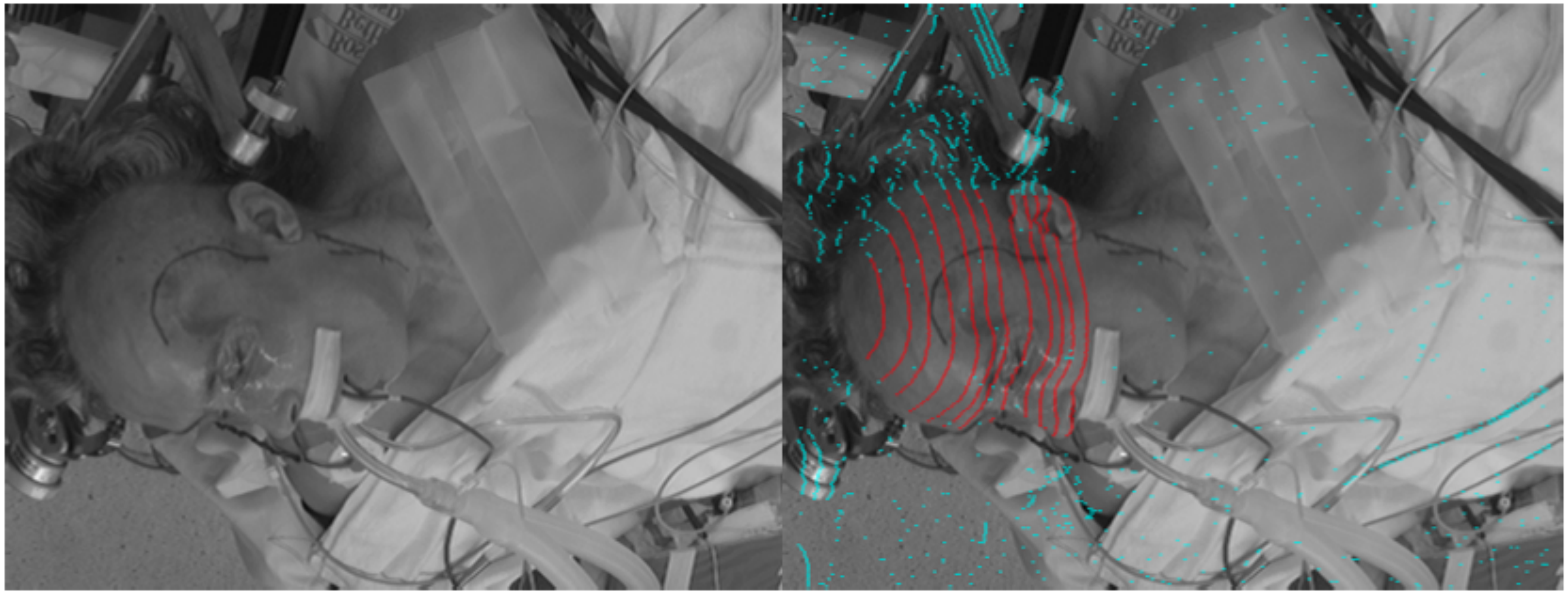


AI-Applications: Product Recommendation



AI-Applications: Image Guided Surgery

Enable surgeons to visualize internal structures through an automated overlay of 3D reconstructions of internal anatomy on top of live video views of a patient



AI-Applications: Speech Recognition

AI-Applications: Exploration of the Universe

Intelligent Agents

Agents

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators

Human agent:

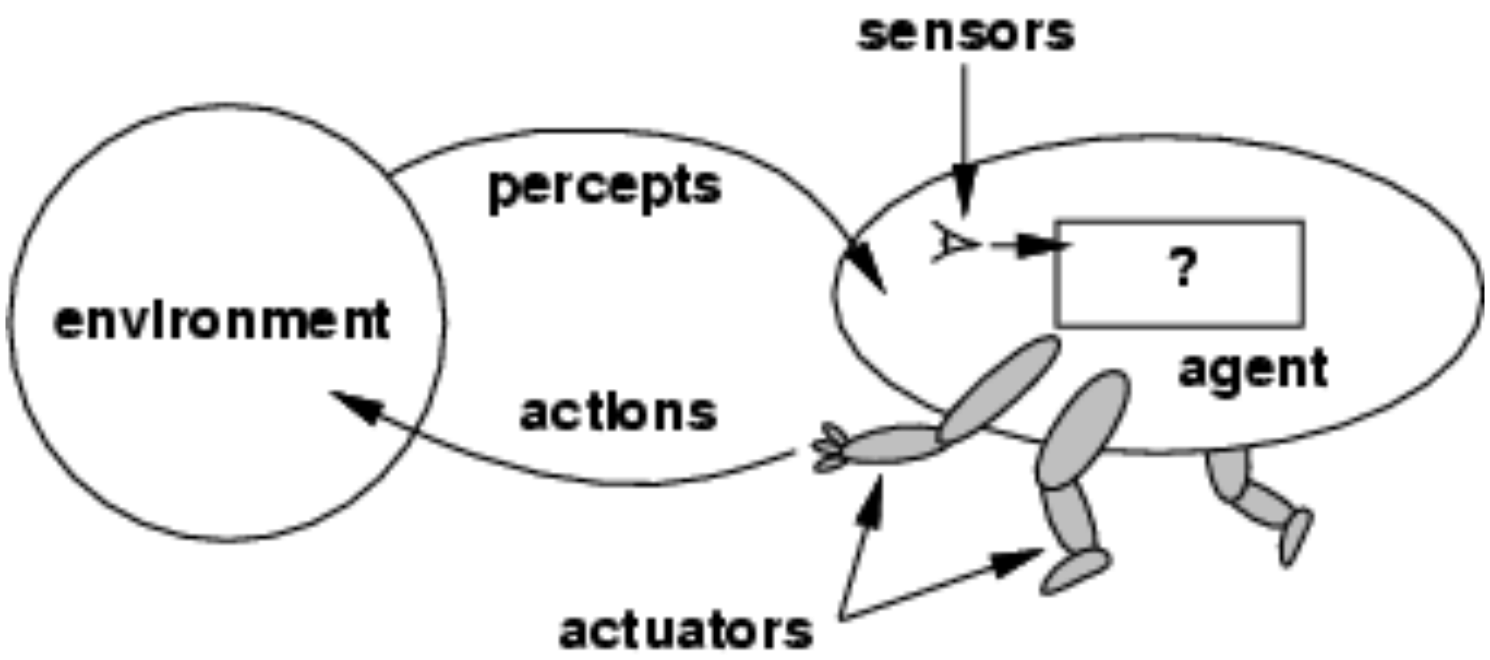
eyes, ears, and other organs for sensors;

hands, legs, mouth, and other body parts for actuators

Robotic agent:

cameras and infrared range finders for sensors; various motors for actuators

Agents and environments



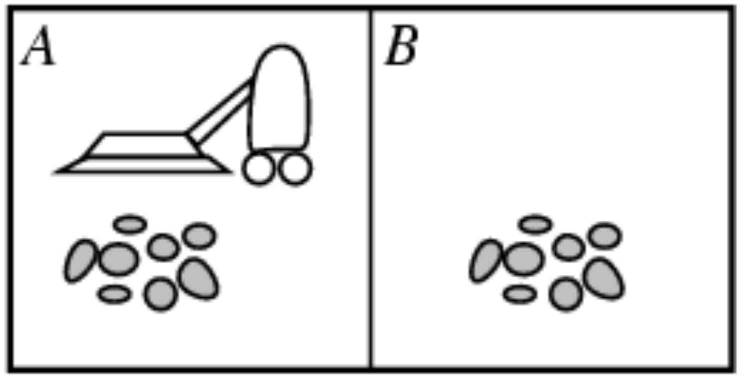
The agent function maps from percept histories to actions:

$$[f: P^* \rightarrow A]$$

The agent program runs on the physical architecture to produce f

agent = architecture + program

Vacuum-cleaner world



Percepts: location and state of the environment, e.g., [A,Dirty], [B,Clean]

Actions: *Left*, *Right*, *Suck*, *NoOp*

Rational agents

Rational Agent: For each possible percept sequence, a rational agent should select an action that is *expected* to maximize its performance measure, based on the evidence provided by the percept sequence and whatever built-in knowledge the agent has.

Performance measure: An objective criterion for success of an agent's behavior

E.g., performance measure of a vacuum-cleaner agent could be amount of dirt cleaned up, amount of time taken, amount of electricity consumed, amount of noise generated, etc.

Rational agents

Rationality is distinct from omniscience (all-knowing with infinite knowledge)

Agents can perform actions in order to modify future percepts so as to obtain useful information (information gathering, exploration)

An agent is autonomous if its behavior is determined by its own percepts & experience (with ability to learn and adapt)

without depending solely on build-in knowledge

Task Environment

Before we design an intelligent agent, we must specify its “task environment”:

PEAS:

Performance measure
Environment
Actuators
Sensors

PEAS

Example: Agent = taxi driver

Performance measure: Safe, fast, legal, comfortable trip, maximize profits

Environment: Roads, other traffic, pedestrians, customers

Actuators: Steering wheel, accelerator, brake, signal, horn

Sensors: Cameras, sonar, speedometer, GPS, odometer, engine sensors, keyboard

PEAS

Example: Agent = Medical diagnosis system

Performance measure: Healthy patient, minimize costs, lawsuits

Environment: Patient, hospital, staff

Actuators: Screen display (questions, tests, diagnoses, treatments, referrals)

Sensors: Keyboard (entry of symptoms, findings, patient's answers)

PEAS

Example: Agent = Part-picking robot

Performance measure: Percentage of parts in correct bins

Environment: Conveyor belt with parts, bins

Actuators: Jointed arm and hand

Sensors: Camera, joint angle sensors

Agent types

Five basic types in order of increasing generality:

Table Driven agent

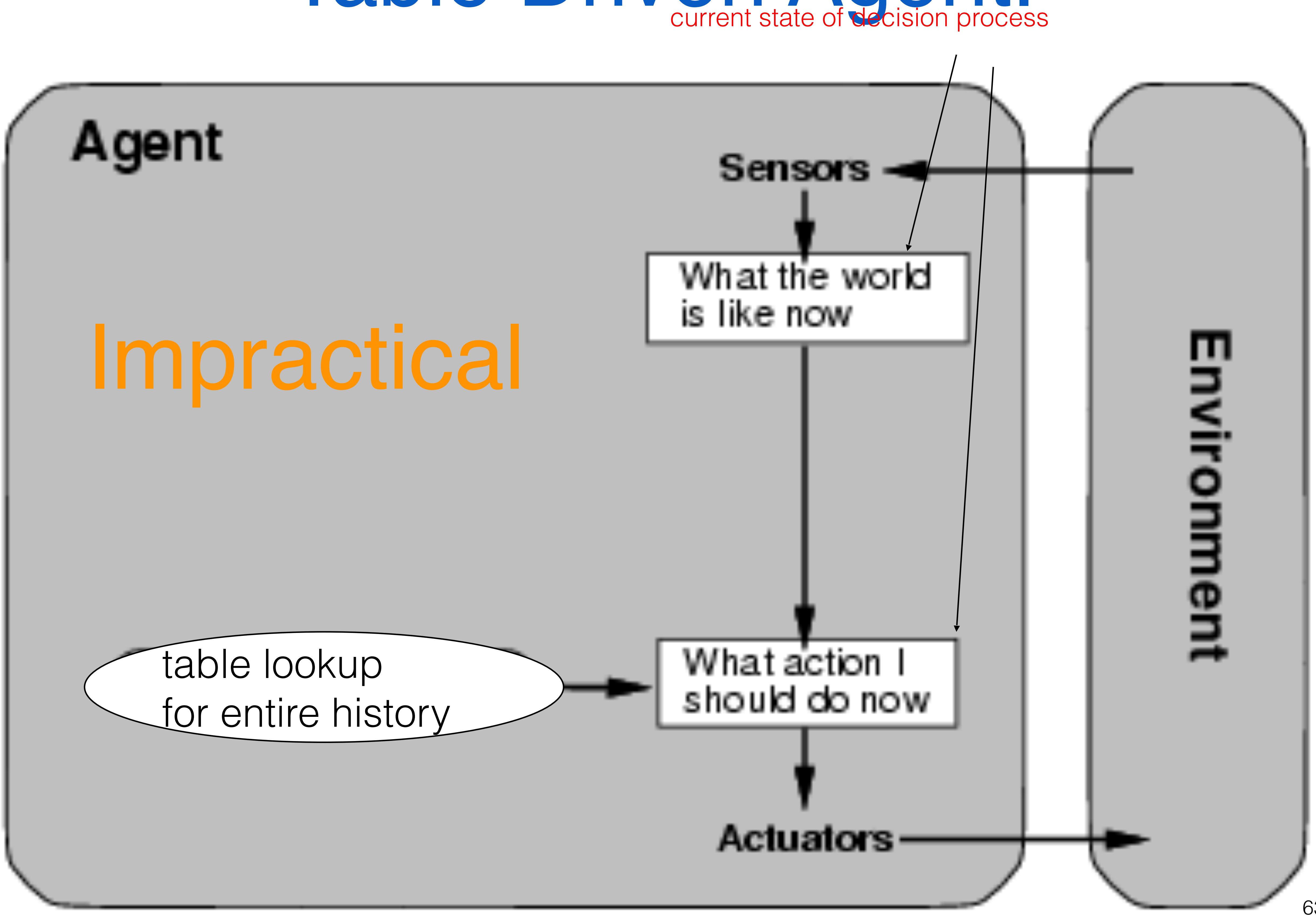
Simple reflex agents

Model-based reflex agents

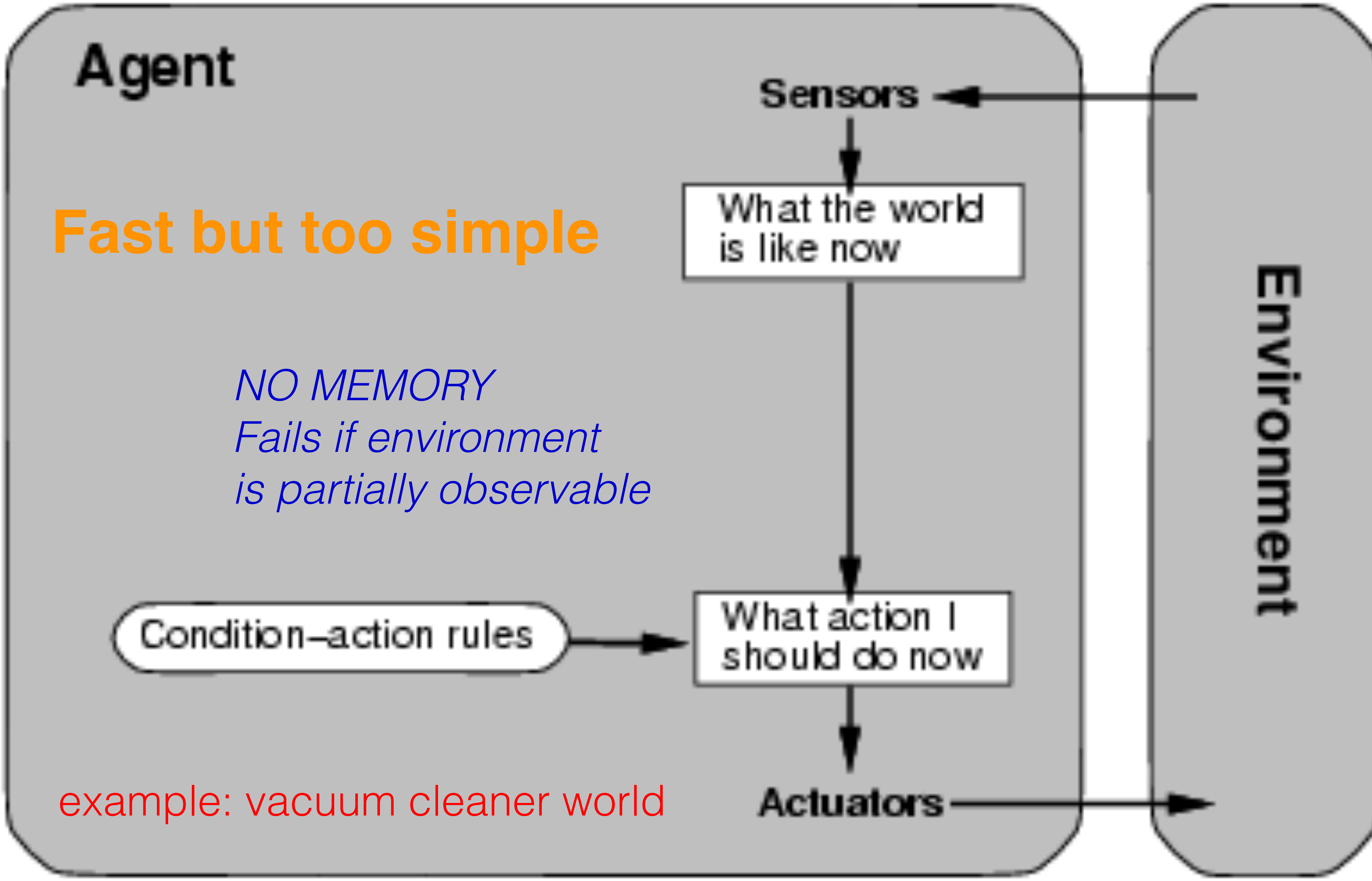
Goal-based agents

Utility-based agents

Table Driven Agent.



Simple reflex agents



Fast but too simple

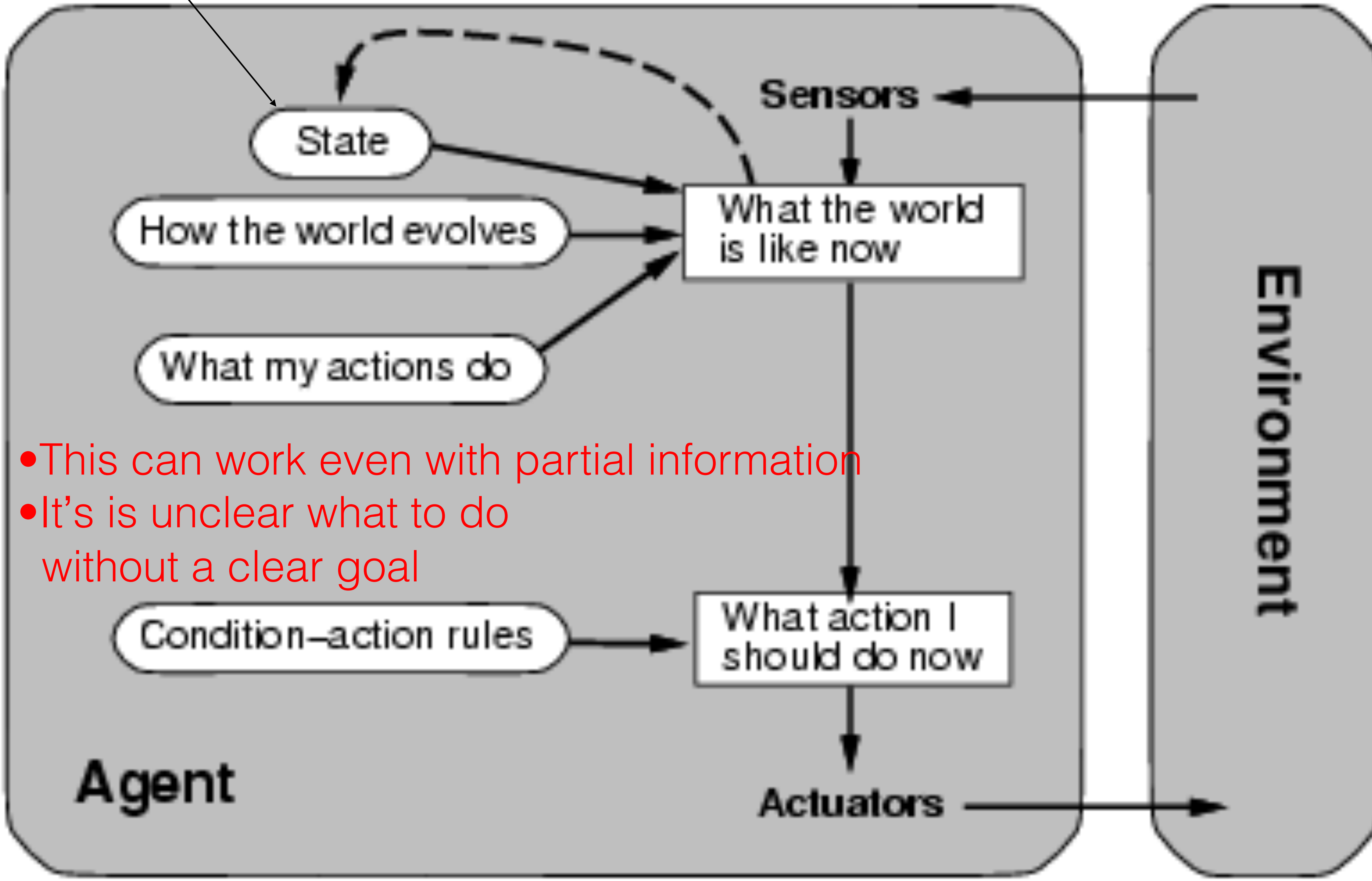
NO MEMORY
Fails if environment is partially observable

example: vacuum cleaner world

Model-based reflex agents

description of
current world state

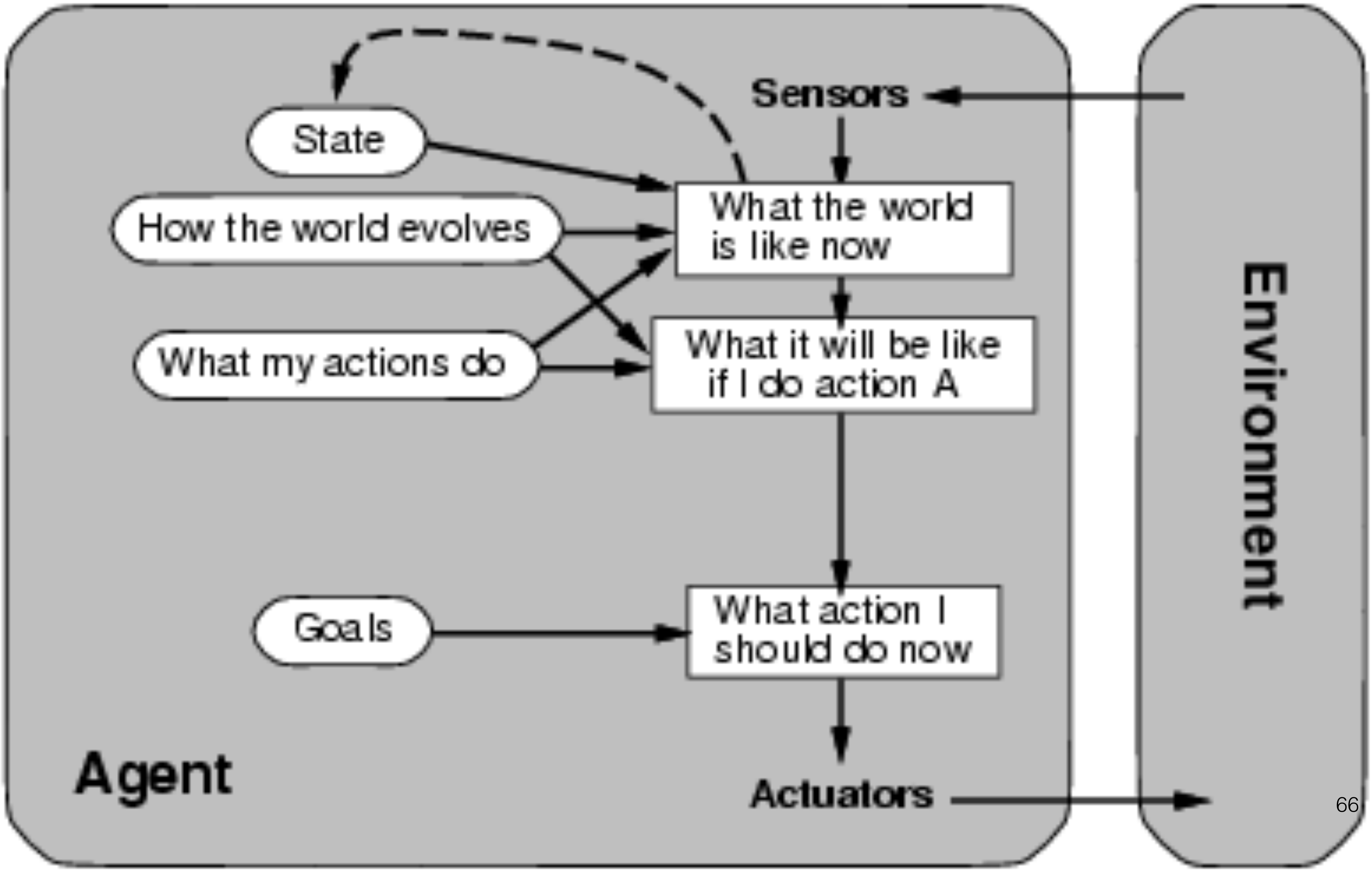
Model the state of the world by:
modeling how the world chances
how it's actions change the world



- This can work even with partial information
- It's is unclear what to do without a clear goal

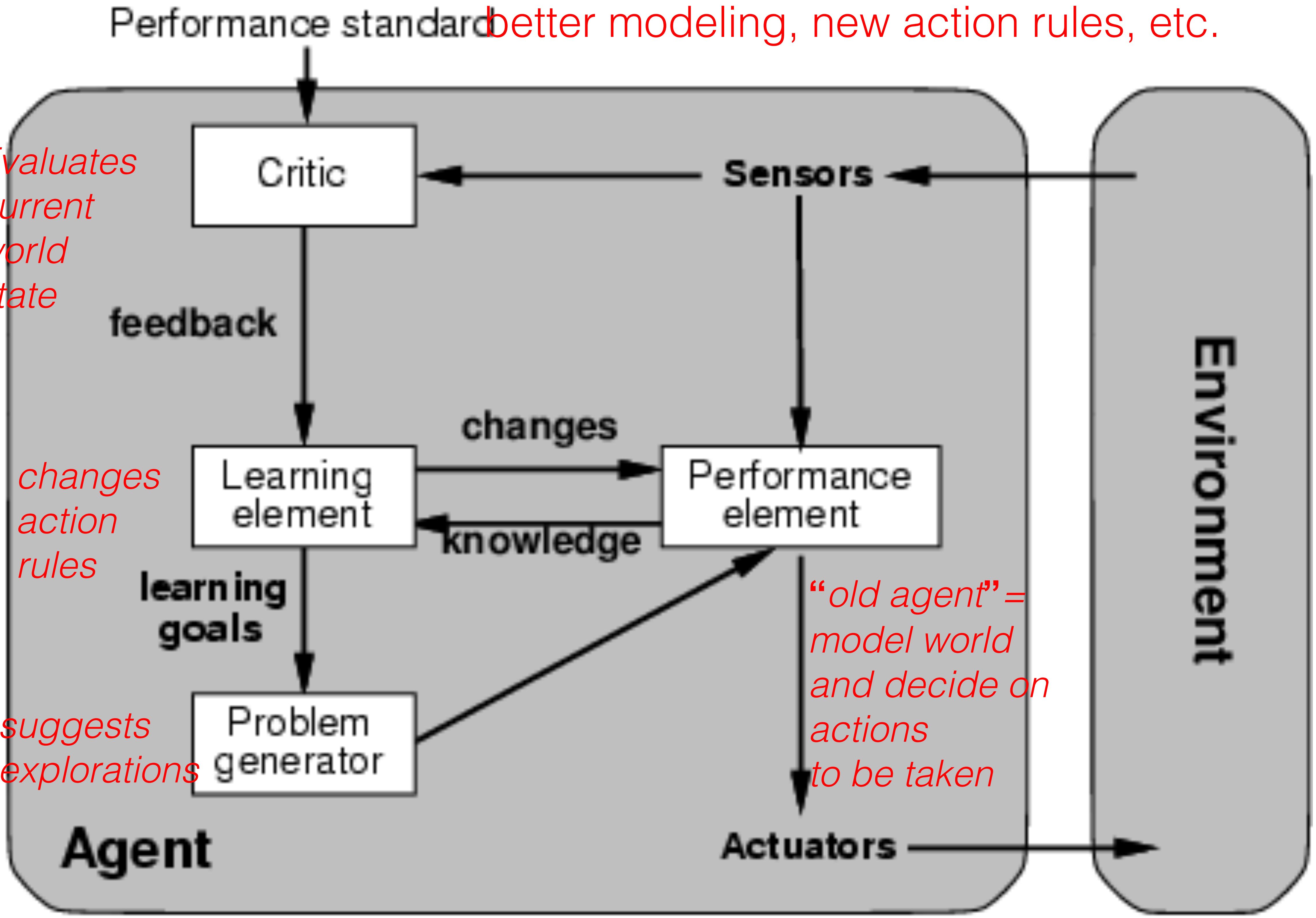
Goal-based agents

Goals provide reason to prefer one action over the other.
We need to predict the future: we need to plan & search



Learning agents

How does an agent improve over time?
By monitoring it's performance and suggesting better modeling, new action rules, etc.



Evaluates current world state

changes action rules

suggests explorations

"old agent" = model world and decide on actions to be taken