

### Definition of AI

**Acting humanly:** The Turing Test approach

**Thinking humanly:** The cognitive modeling approach

**Thinking rationally:** The "laws of thought" approach (Logic)

**Acting rationally:** The rational agent approach

### Turing test

**natural language processing** to enable it to communicate successfully in English;

**knowledge representation** to store what it knows or hears;

**automated reasoning** to use the stored information to answer questions and to draw new conclusions;

**machine learning** to adapt to new circumstances and to detect and extrapolate patterns.

*total Turing test*

**computer vision** to perceive objects;

**robotics** to manipulate objects and move about.

### Agents and Environments

An **agent** is anything that can be viewed as perceiving its **environment** through **sensors** and acting upon that environment through **actuators**. We use the term **percept** to refer to the agent's perceptual inputs at any given instant. An agent's **percept sequence** is the complete history of everything the agent has ever perceive.

### PEAS

Performance measure, Environment, Actuators, Sensors

### Knowledge Base

Conceptually, a set of sentences;  
.Defined by TELL/ASK interface

### Declarative Approach

Program an agent by TELLing it things

Equivalently, construct and install a KB

Advantages

1. Flexibility: knowledge independent of how it would be used
2. Transparency to humans
3. Agent behavior malleable via language

### Knowledge Representation

**Knowledge representation language:**

notation for expressing a KB

**Consist of**

Syntax: defines the legal sentences

Semantics: facts in the world to which sentences correspond, an interpretation for symbols in the logic

**Logic:** KR language with well-defined syntax and semantics

**Model:** Specifies truth or falsity of sentences

### Properties of Sentences

**Valid:** True in all models

**Satisfiable:** True in some model

### Rational agent

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

### Autonomy

A system is autonomous that its behavior is determined by its own percepts, rather than the prior knowledge of its designer.

### Coherence

Actions must be consistent with beliefs and desires. Necessary for knowledge-level understanding of computer programs.

### Agent Designs

Table Lookup, Simple Reflex, Model-based, Goal-based, Utility-based, Learning

### Environment Properties

fully/partially observable, single/multi, deterministic/stochastic, episodic/sequential, static/dynamic, discrete/continuous, known/unknown

### Admissibility and Consistency

**Admissibility:**  $h(n) \leq c(n)$ , where  $c(n)$  is the true cost of a solution along the current path through  $n$ .

**Consistency:**  $h(n) \leq c(n, a, n') + h(n')$ .

**Optimality:** If  $h$  is admissible and consistent,  $A^*$  is optimal.

$A^*$  is optimal, complete and optimally efficient among all algorithms that extend search paths from root.

### Entailment and Inference

**Entailment:**  $\alpha \models \beta$  if and only if  $M(\alpha) \subseteq M(\beta)$ .

Truth of  $\beta$  is contained in  $\alpha$ .  $\alpha \models \beta$  if and only if the sentence  $(\alpha \Rightarrow \beta)$  is valid.  $\alpha \equiv \beta$  if and only if  $\alpha \models \beta$  and  $\beta \models \alpha$ .

**Inference:**  $\alpha \vdash \beta$  means  $\beta$  can be derived from  $\alpha$ .

An inference algorithm that derives only entailed sentences is called **sound**.

An inference algorithm is **complete** if it can derive any sentence that is entailed



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Published 25th February, 2016.

Last updated 25th February, 2016.

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## FOL to CNF

- 1.Translate bidirectionals to implications
- 2.Translate implications to disjunctions
- 3.Move negations inward (Use De Morgan's laws until only atoms are negated)
- 4.Standardize variables
- 5.Eliminate existentials via skolemization
- 6.Drop universal quantifiers
- 7.Distribute and associate into CNF

## Uninformed search strategies

Breadth-first, Uniform-cost, Depth-first, Depth-limited, Iterative-deepening, Bidirectional, Graph search

## Analysis

Criterion	BFS	UC
Complete	Yes	Yes
Optimal	Yes	Yes
Time	$O(b^{d+1})$	$O(b^{1+\lceil C^*/e \rceil})$
Space	$O(b^{d+1})$	$O(b^{1+\lceil C^*/e \rceil})$

## Analysis

Criterion	DFS	DLDFS	IDDFS
Complete	No	No	Yes
Optimal	No	No	Yes
Time	$O(b^m)$	$O(b^l)$	$O(b^d)$
Space	$O(bm)$	$O(bL)$	$O(bd)$

## Informed Search

Priority-first(PFS), Greedy, A\*, Iterative-deepening A\*, heuristics and admissibility/consistency

## Flavors of PFS

Number of edges from origin: BFS  
 $g(n)$ , the path cost from the initial state(node) to node n: UCS(Dijkstra)  
 $h(n)$ , the estimated path cost from node n to goal: Greedy Search  
 $f(n)=g(n)+h(n)$ , the estimated cost of a path passing through n: A\* search

## Memory-bounded heuristic search

### iterative-deepening A\* (IDA\*)

**Recursive best-first search (RBFS)**: best first search with linear space

## Local search strategies

Hill-climbing/stochastic, beam, simulated annealing, genetic algorithms

## Local search summary

### Key advantages

- 1.Very little memory
- 2.Can often find reasonable solutions in large or infinite state spaces where systematic approaches are unsuitable
- 3.Better answers the more time spent

### Disadvantages

Usually incomplete and not optimal

## Constraint propagation

**Definition**: Propagating the implications of a constraint on one variable onto other variables.

**k-consistent**: for any consistent assignment of k-1 variables, exists consistent value of any kth(Node/Arc/Path)

**Strongly k-consistent**: j-consistent for all j less than or equal to k

## Constrain Satisfaction Search

### Backtracking

Minimum remaining values heuristic: choose variable with fewest legal values remaining

Degree heuristic: choose variable with largest number of constraints

**Forward checking**: delete inconsistent values ahead

### Backjumping

Basic: backtrack to most recent decision

Conflict-Directed: backtrack to most recent variable in conflict with

