### PEAS

The Performance measure

The Environment in which the agent will operate

The Actuators that the agent will use to affect the environment

The Sensors that the agent will use to perceive the environment

### Env prop

Fully vs partially observable (can be unobservable too)

Single agent vs multiagent

multiagent: competitive vs. cooperative

Deterministic vs. nonderministic (stochastic)

nonderministic: next state is NOT completely determined by the current state and agent action

Episodic vs. sequential

sequential: current decision / action COULD affect all future decisions / actions

Static vs. dynamic

Static: environment CANNOT change while the agent is taking its time to decide

Discrete vs. continuous

continuous: time changes are continuous

Known vs. unknown

known: agent knows all outcomes to its actions

unknown: learning and exploration can be necessary

### State representations

Atomic

state representation has NO internal structure

Factored

state representation includes fixed attributes (which can have values)

Structured

state representation includes objects and their relationships

### Typical agent arch

Simple reflex agent

uses condition-action rules

Model-based reflex agent

keeps track of the unobserved parts of the environment by maintaing internal state:

“how the world works”: state transition model

how percepts and environment is related: sensor model

Goal-based reflex agent

maintains the model of the world and goals to select decisions (that lead to goal)

Utility-based reflex agent

maintains the model of the world and utility function to select PREFERRED decisions (that lead to the best expected utility: avg (EU \* p))

### Search perf

Completeness: Is the algorithm guaranteed to find a solution when there is one, and to correctly report failure when there is not?

Cost optimality: Does it find a solution with the lowest path cost of all solutions?

### Min-Max

I don’t know what move my opponent will choose, but I am going to ASSUME that it is going to be the best / optimal option

At every leaf node the MinMax value (utility at leaf node) is calculated,

For every MAX Player node, the current LARGEST child MinMax value is saved in

For every MIN Player node, the current SMALLEST child MinMax value is saved in

If at a MIN Player node m the current value , then the search at node m can end. Here is the LARGEST value of a MAX Player node in the path from the root to node m,

If at a MAX Player node n the current value , then the search at node n can end. Here is the SMALLEST value of a MIN Player node in the path from the root to node n.

### Constraint Satisfaction Problem (CSP)

a set of variables

a set of domains

a set of constraints C that specify allowable combinations of value

If NO constraints violated: consistent assignment

If ALL variables have a value: complete assignment

If SOME variables have NO value: partial assignment

SOLUTION: consistent and complete assignment

PARTIAL SOLUTION: consistent and partial assignment

### local consistency

Remove inconsistent values from variable domains as we go as they would make certain assignments inconsistent later anyway

Node consistency

a single variable is node-consistent (in a constraint graph) if all the values in its domain satisfy variable unary constraints

Arc consistency

a single variable is arc-consistent (in a constraint graph) if all the values in its domains satisfy ALL its binary constraints

Path consistency

two variable set {Xi, Xj} is path-consistent (in a constraint graph) with respect to a third variable Xm if for EVERY assignment {Xi = a, Xj = b} there is an assignment to Xm (between Xi and Xj) that satisfies constraints on {Xi, Xm} and {Xm, Xj}.

### Logical Entailment

A set of sentences (called premises) logically entails a sentence (called a conclusion) if and only if every truth assignment that satisfies the premises also satisfies the conclusion

PREMISES CONCLUSION

### Conjunctive Normal Form CNF

A sentence is in CNF if and only if consists of conjunction: of clauses.  
A clause Ki consists of a disjunction of literals

eg.

Definite Clauses  
A sentence can be called a definite clause if and  
only if it is a disjunction of literals of which  
EXACTLY one is positive. For example:  
(¬p ∨ ¬q ∨ r)

Horn Clauses  
A sentence can be called a Horn clause if and only if  
it is a disjunction of literals of which AT MOST one  
is positive. For example:  
(¬p ∨ ¬q ∨ r)   
is a Horn clause (goal clause → no positive literals).

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Proof by Resolution

Recall that we can show that KB entails sentence  
Q (or Q follows from KB):  
KB ⊨ Q  
by proving that:  
(KB ∧ ¬ Q) ⇔ ⊥  
(show that KB ∧ ¬ Q is a contradiction / empty clause)

**The process of proving by resolution is as follows:**  
A. Formalize the problem: “English to Propositional Logic”  
B. derive KB ∧ ¬ Q  
C. convert KB ∧ ¬ Q into CNF (“standardized”) form  
D. Apply resolution rule to resulting clauses. New clauses  
will be generated (add them to the set if not already  
present)  
E. Repeat (C) until:  
a. no new clause can be added (KB does NOT entail Q)  
b. last two clauses resolve to yield the empty clause (KB  
entails Q)

### Predicate (First-Order) Logic to CNF

Variables and quantifiers are a challenge:

1. Eliminate all equivalences ⇔ and implications ⇒

2. Reduce the scope of all ¬ to single term (De Morgan)

3. Make all variable names unique (standardize apart)

4. Move quantifiers left (convert to prenex normal form)

5. Eliminate Existential quantifiers (skolemization)

6. Eliminate Universal quantifiers

7. Convert to conjunction of disjuncts

8. Create separate clause for each conjunct

**Belief state:** a set of all possible environment states  
that the agent can be in and needs to keep track of  
to handle uncertainty.

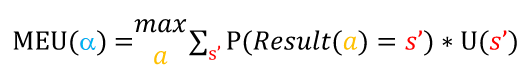
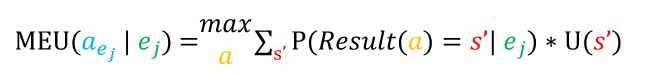
### Decision Theory

Decisions: every plan (actions) leads to an  
outcome (state)  
 Agents have preferences (preferred outcomes)  
 Preferences → outcome utilities  
 Agents have degrees of belief (probabilities) for  
actions  
Decision theory = probability theory + utility theory

### Conditional Probability

### Bayes’ Rule

### Value of Perfect Information

The value/utility of best action a without additional  
evidence (information) is :  
  
If we include new evidence/information ( ) given by  
some variable Ej, value/utility of best action a becomes:  
  
The value of additional evidence/information from Ej is:  
  
using our current beliefs about the world.

|  |  |  |
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| Supervised | Unsupervised | Reinforcement |
| Supervised learning is one of the most common techniques in machine learning . It is based on known relationship(s) and patterns within data (for e x a m p l e : r e l a t i o n s h i p b e t w e e n i n p u t s a n d outputs). F re q ue nt l y us e d t y pe s: r e g r e s s i o n , a n d classification. | Un s u p e r v i s e d l e a r n i n g involves finding underlying p a t t e r n s w i t h i n d a t a . Typically used in clustering d a t a p o i n t s ( s i m i l a r customers, etc.) | Reinforcement learning is i n s p i r e d b y b e h a v i o ra l psychology. It is based on a rewarding / punishing an algorithm. Rewards and punishments are based on algorithm’s a c t i o n w i t h i n i t s environment. |

