CS2109S
AY22/23 Sem 2
github.com/jasonqiu212

01. Introduction

- **Agent** - Anything that can perceive its environment through sensors and acting upon that env. through actuators
- **Agent Function** - Maps from percept histories to actions
- **Rational Agent** - Chooses an action that is expected to maximize its performance measure, given by percept sequence and built-in knowledge
- **Autonomous Agent** - If behavior is determined by its own expereince

Performance Measure of Function

- Motivation: For an agent to do the right thing, need a measure of goodness
- Performance vs. Cost

1. Best for whom?
2. What are we optimizing?
3. What information is available?
4. What are the side effects and costs?

Defining the Problem: PEAS

1. Performance measure
2. Environment
3. Actuators
4. Sensors

Characterizing the Environment

1. **Fully observable** - (vs. Partially) Agent's sensors can access complete state of env. all the time
2. **Deterministic** - (vs. Stochastic) Next state of env. is determined by **current state** and **action executed by agent**
   - **Strategic** - If env. is deterministic except for actions of other agents
3. **Episodic** - (vs. Sequential) Agent's experience is divided into atomic **episodes**, where each episode includes perceiving and an action, and **action depends on episode** itself
4. **Static** - (vs. Dynamic) Env. is unchanged while agent is deciding
   - **Semi** - Time does not affect env., but affects performance score
5. **Discrete** - (vs. Continuous) Discrete num. of percepts and actions
6. **Single Agent** - (vs. Multi-agent) Agent operating by itself in an env.

Implementing Agents (in ascending complexity)

1. **Simple Reflex Agents** - Fixed conditional rules
2. **Model-based Reflex Agents** - Stores percept history to make decisions about internal model of world with conditional rules. Eg. Roomba
3. **Goal-based Agents** - Keep in mind a goal and action aims to achieve it
4. **Utility-based Agents** - Find best way to achieve goal
5. **Learning Agents** - Learn from previous experiences

Exploitation vs. Exploration

- **Exploitation** - Maximize expected utility using current knowledge of world
- **Exploration** - Learn more about the world to improve future gains. May not always maximize performance measure.

02. Searching

- Deterministic, fully observable
- **Tree Search** - Can revisit nodes
- **Graph Search** - Tracks visited (Tree Search + Memoization)
- **Uninformed Search** - Uses only information available in problem definition

Formulating the Problem

1. How to represent state in problem?
2. Initial state
3. Actions: Successor function
4. Goal test
5. Path cost

- **Abstraction Function** - Maps abstracted representation to real world state
- **Representation Invariant** - $I(c) = \textbf{True} \rightarrow \exists a \textbf{ s.t. } AF(c) = a$

Breadth-first Search

- Idea: Expand shallowest unexpanded node using **queue**
- Given: b: Branching factor and d: Depth of optimal solution
- Complete: Yes (if tree is finite)
- Time: $O(b^{d+1})$
- Space: $O(b^d)$
- Optimal: Yes (if cost = 1)
- BFS is Uniform-cost Search with same cost

Uniform-cost Search

- Idea: Expand least-cost unexpanded node using **priority queue** (Dijkstra's)
- Given: C^*: Cost of optimal solution
- Complete: Yes (if step cost $\geq \epsilon$ where $\epsilon \geq 0$)
- Time: $O(b^{(C^*/\epsilon)})$ (C^*/ϵ is approx. number of layers)
- Space: $O(b^{(C^*/\epsilon)})$
- Optimal: Yes

Depth-first Search

- Idea: Expand deepest unexpanded node using **stack**
- Given: m: Maximum depth of tree
- Complete: No (fails with infinite depth or loops)
- Time: $O(b^m)$
- Space: $O(bm)$ (better than BFS)
- Optimal: No

Depth-limited Search

- DFS with depth limit I where nodes at depth I have no children
- Time: $b^0 + b^1 + ... + b^{(d-1)} + b^d = O(b^d)$

Iterative Deepening Search

- Idea: Try different depths for depth-limited search
- Complete: Yes
- Time: $(d+1)b^0 + db^1 + ... + b^d = O(b^d)$ (More overhead than DLS)
- Space: $O(bd)$

Summary

	BFS	Uniform Cost	DFS	DLS	IDS
Complete	Yes	Yes	No	No	Yes
Time	$O(b^d)$	$O(b^{C^*/\epsilon})$	$O(b^m)$	$O(b^l)$	$O(b^d)$
Space	$O(b^d)$	$O(b^{C^*/\epsilon})$	$O(bm)$	$O(bl)$	$O(bd)$
Optimal	Yes	Yes	No	No	No

Bidirectional Search

- Idea: Search both forwards from initial state and backwards from goal state. Stop when searches meet.
- Time: $O(2b^{d/2})$
- Operators must be reversible
- Can have many goal states
- How to check if node intersects with other half?

03. Informed Search

04. Introduction to Machine Learning

- A machine learns if it improves performance P on task T based on experience E. Where T must be fixed, P must be measurable, E must exist

Types of Feedback

- **Supervised** - Correct answer given for each example
  - **Regression** - Predict results within continuous output
  - **Classification** - Predict results in discrete output
- **Unsupervised** - No answers given
- **Weakly supervised** - Answer given, but not precise
- **Reinforcement** - Occasional rewards given

Decision Trees

- DT can express any function of input attributes, if data is consistent
- Goal: Make DT **compact**. How?

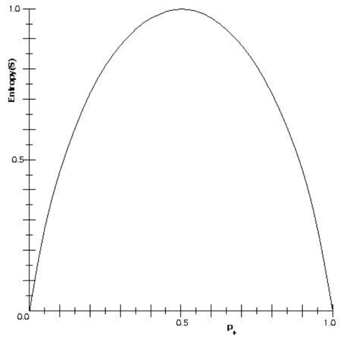
Information Theory

- Idea: Choose attribute that splits examples into subsets that are ideally 'all positive' or 'all negative'
- **Entropy** - Measure of randomness in set of data

$$I(P(v_1), ..., P(v_n)) = -\sum_{i=1}^{n} P(v_i) \log_2 P(v_i)$$

- For data with p positive examples and n negative examples:

$$I(\frac{p}{p+n}, \frac{n}{p+n}) = -\frac{p}{p+n} \log_2 \frac{p}{p+n} - \frac{n}{p+n} \log_2 \frac{n}{p+n}$$



- **Information Gain** - (IG) Reduction in entropy from attribute test
- Goal: Choose attribute with largest information gain
- Intuition: IG = Entropy of this node - Entropy of children nodes
- Given chosen attribute A with v distinct values:

$$\text{remainder}(A) = \sum_{i=1}^{v} \frac{p_i + n_i}{p+n} I(\frac{p_i}{p_i + n_i}, \frac{n_i}{p_i + n_i})$$

$$IG(A) = I(\frac{p}{p+n}, \frac{n}{p+n}) - \text{remainder}(A)$$

- **Decision Tree Learning** - Recursively choose attributes with highest IG
- IG is not the only way. Can use whatever objective function that achieves the criteria we want.

Performance Measurement

- **Correctness** - Correct if $\hat{y} = y$
- **Accuracy** - $\frac{1}{m} \sum_{j=1}^{m} (\hat{y_j} = y_j)$
- Confusion Matrix:

		Actual Label	
		+ve	-ve
Predicted Label	+ve	TP True Positive	FP False Positive
	-ve	FN False Negative	TN True Negative

- Accuracy = $\frac{TP+TN}{TP+FN+FP+TN}$
- **Precision** - $\frac{TP}{TP+FP}$ **Recall** - $\frac{TP}{TP+FN}$
- Type I Error: FP Type II Error: FN
- FP Rate = $\frac{FP}{FP+TN}$ TP Rate = $\frac{TP}{TP+FN}$

Pruning

- Motivation: DT overfits to training set, but performs poorly on test set
- Occam's Razor: Simple hypothesis preferred
- **Pruning** - Prevent node from being split when split does not split cleanly
  - E.g. Min-sample, Max-depth

05. Linear Regression