# Learning Objectives

At the end of the class you should be able to:

- define a directed graph
- represent a problem as a state-space graph

# Searching

- Often we are not given an algorithm to solve a problem, but only a specification of what is a solution — we have to search for a solution.
- A typical problem is when the agent is in one state, it has a set of deterministic actions it can carry out, and wants to get to a goal state.
- Many AI problems can be abstracted into the problem of finding a path in a directed graph.
- Often there is more than one way to represent a problem as a graph.

# State-space Search

- flat or modular or hierarchical
- explicit states or features or individuals and relations
- static or finite stage or indefinite stage or infinite stage
- fully observable or partially observable
- deterministic or stochastic dynamics
- goals or complex preferences
- single agent or multiple agents
- knowledge is given or knowledge is learned
- perfect rationality or bounded rationality

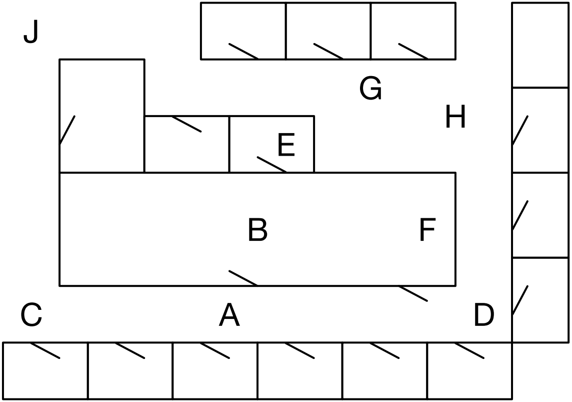
# State-space Problem

A state-space problem consists of

- a set of states
- a subset of states called the start states
- a set of actions
- an action function: given a state and an action, returns a new state
- a set of goal states, specified as function, $goal(s)$
- a criterion that specifies the quality of an acceptable solution.

# Example Problem for Delivery Robot

The robot is at $A$ and the goal is to get to $G$:



# Directed Graphs

- A (directed) graph consists of a set $N$ of nodes and a set $A$ of ordered pairs of nodes, called arcs.
- Node $n_2$ is a neighbor of $n_1$ if there is an arc from $n_1$ to $n_2$. That is, if $\langle n_1, n_2 \rangle \in A$.
- A path is a sequence of nodes $\langle n_0, n_1, \ldots, n_k \rangle$ such that $\langle n_{i-1}, n_i \rangle \in A$.
- Given start nodes and goal nodes, a solution is a path from a start node to a goal node.
- When there is a cost associated with arcs, the cost of a path is the sum of the costs of the arcs in the path:

$$cost(\langle n_0, n_1, \ldots, n_k \rangle) = \sum_{i=1}^{k} cost(\langle n_{i-1}, n_i \rangle)$$

An optimal solution is one with minimum cost.

# What is a state?

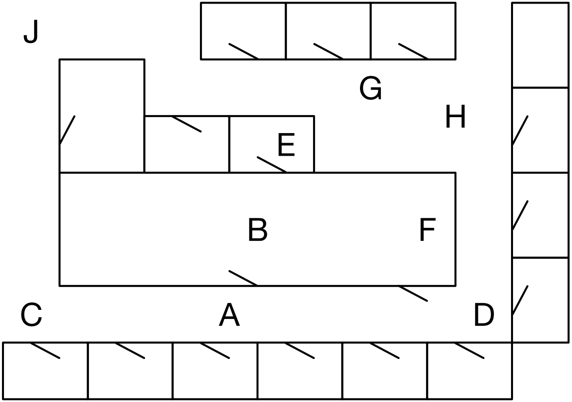
A state needs to include enough information to

- determine what is the next state
- determine whether the goal is achieved
- determine the cost.

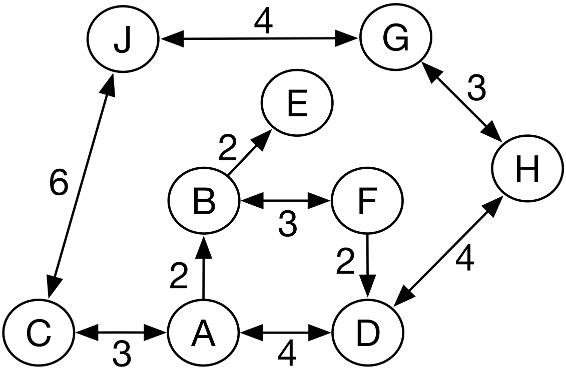
Often there are many options for what to include in the state.
Keep the states as simple as possible but no simpler.

# Example Problem for Delivery Robot

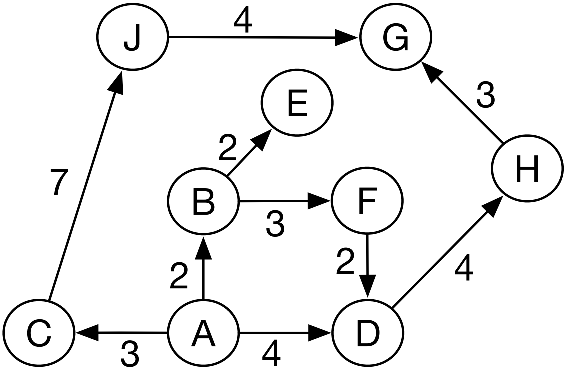
The robot is at $A$ and the goal is to get to $G$:



# State-Space Graph for the Delivery Robot



# State-Space Graph for the Delivery Robot (Acyclic)



# Example: Google Maps

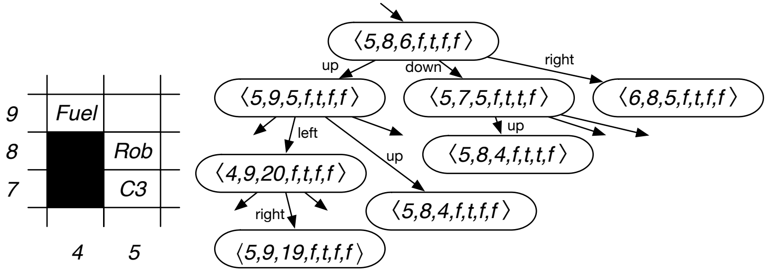
- single start location and goal location
- cost is estimated time
- state needs to include direction because the cost depends on directions (e.g., turning left).

# Partial Search Space for a Video Game

Grid game: Rob is on a grid and can move up, down, left or right and needs to collect coins $C_1$, $C_2$, $C_3$, $C_4$, without running out of fuel, and end up at location $(1,1)$:

State: $< X\text{-}pos,\ Y\text{-}pos,\ Fuel, C_1,\ C_2,\ C_3,\ C_4 >$

Goal: $<$ 1, 1, ?, t, t, t, t$>$



# Robot Cleaner

- 2 rooms, one cleaning robot
- rooms can be clean or dirty
- robot actions:
  suck: makes the room that the robot is in clean
  move: move to other room
- Goal: have both rooms clean
- How many states are there? What are they?