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
- explain how a generic searching algorithm works

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

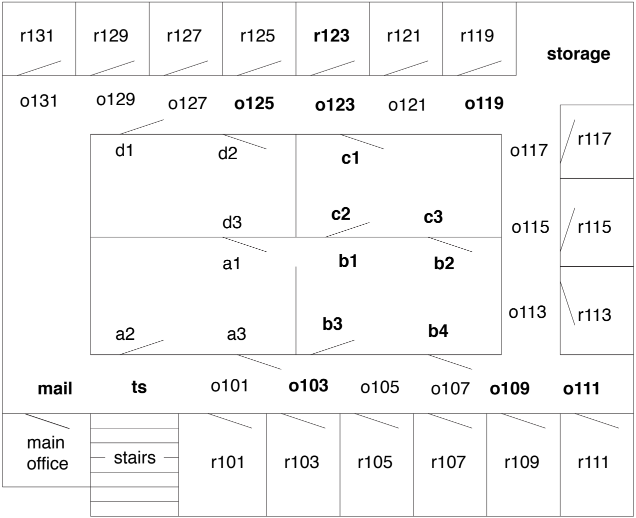
State-space Problem

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 wants to get from outside room 103 to the inside of room 123.



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- The length of path $\langle n_0, n_1, \ldots, n_k \rangle$ is k.
- Given a set of start nodes and goal nodes, a solution is a path from a start node to a goal node.

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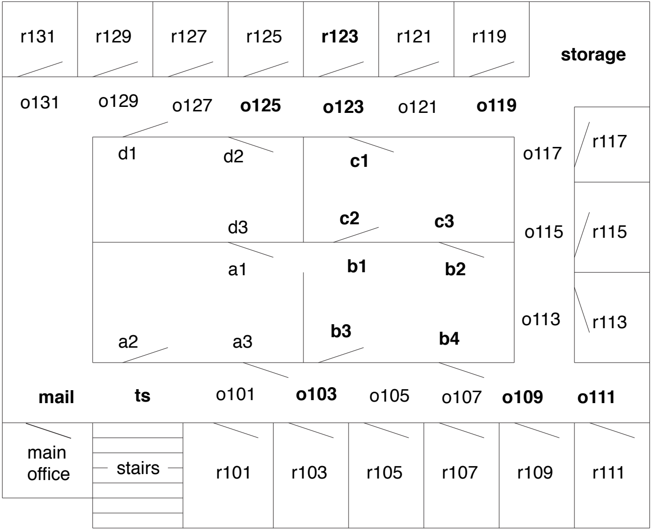
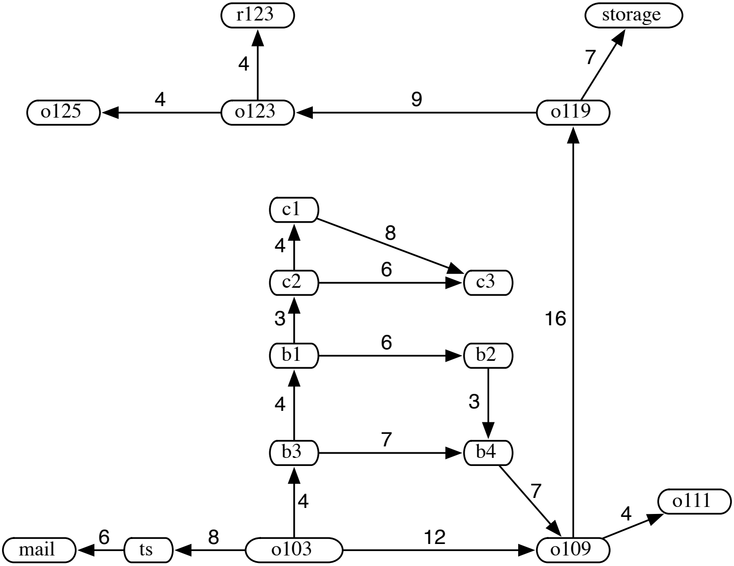


State-Space Graph for the Delivery Robot



Example: Google Maps

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
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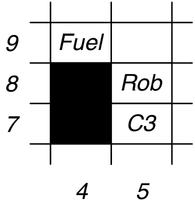
- How many states are there?

Partial Search Space for a Video Game

Grid game: Rob needs to collect coins C_1, C_2, C_3, C_4, without running out of fuel, and end up at location $(1, 1)$:



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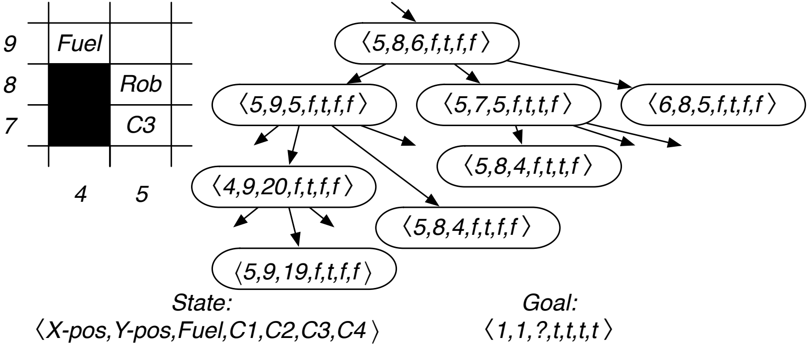
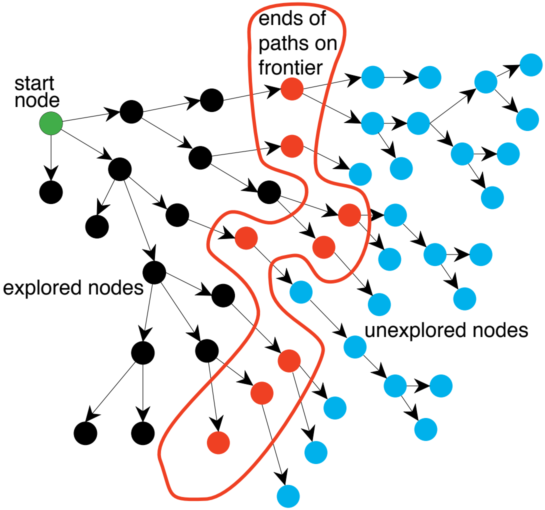


Graph Searching

- Generic search algorithm: given a graph, start nodes, and goal nodes, incrementally explore paths from the start nodes.
- Maintain a frontier of paths from the start node that have been explored.
- As search proceeds, the frontier expands into the unexplored nodes until a goal node is encountered.
- The way in which the frontier is expanded defines the search strategy.

Problem Solving by Graph Searching



Graph Search Algorithm

Input: a graph,
a set of start nodes,
Boolean procedure $goal(n)$ that tests if n is a goal node.

frontier $:= \{\langle s \rangle : s \text{ is a start node}\}$

while *frontier* is not empty:

  select and **remove** path $\langle n_0, \ldots, n_k \rangle$ from *frontier*

  if $goal(n_k)$

    return $\langle n_0, \ldots, n_k \rangle$

  for every neighbor n of n_k

    add $\langle n_0, \ldots, n_k, n \rangle$ to *frontier*

end while

Graph Search Algorithm

- Which value is selected from the frontier at each stage defines the search strategy.
- The neighbors define the graph.
- *goal* defines what is a solution.
- If more than one answer is required, the search can continue from the return.

Optimality Criteria

- Often we don't want any solution, but the best solution or optimal solution.
- Costs on arcs give costs on paths. We want the least-cost path to a goal.