Search: Representation and General Search Procedure

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UBC CS 322 – Search 1

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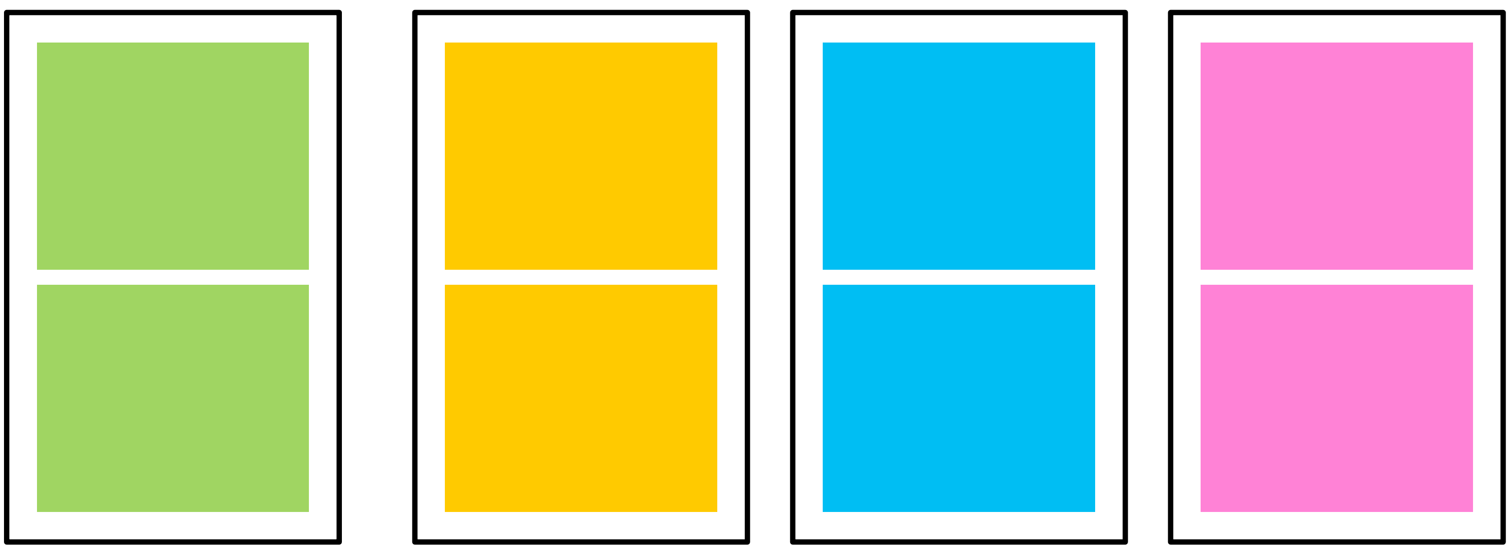
Textbook §3.0 – 3.4

Colored Cards: Do you Have Them?

- If not, please come to the front and pick up
  - 4 index cards
  - 2 Post-it per colour (Blue, Yellow, Green, Pink)
- Use this material to make 4 “voting cards” as below
  - Low budget variant of clickers
  - Please bring them to class every time



Today's Lecture

- Search: motivation
- Simple Search Agent and Examples
- General Search Procedure

Course Map

Dimen-sions / Course Modules	Deterministic vs. Stochastic	Static vs. Sequential	States vs. Features vs. Relations
1. Search	Deterministic	Static	States
2. CSPs	Deterministic	Static	Features
3. Planning	Deterministic	Sequential	States or Features
4. Logic	Deterministic	Static	Relations
5. Uncertainty	Stochastic	Static	Features
6. Decision Theory	Stochastic	Sequential	Features

Search is a powerful tool to know well

- World champion AI programs:
  - Checkers 1994 (unbeatable!)
  - Chess 1997
- Can also be used to solve
  - Constraint satisfaction problems (CSP), course module 2
  - Constraint optimization problems
    - Very important in operations research and in industry
  - Planning, course module 3
  - Problems in game AI
    - Infinite Mario Bros: http://www.youtube.com/watch?v=0s3d1LfjWCI
  - …

Search for Playing Infinite Mario Bros

http://www.youtube.com/watch?v=0s3d1LfjWCI

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Search

- Often we are given a specification of what a solution is, but do not know how we would go about finding one.

⇓

we have to search for a solution

- Enumerate a set of potential partial solutions
- Check to see if they are solutions or could lead to one
- We can recognize a solution once we see one
- **“Generate [potential [partial] solution] and test.”**

Simple Deterministic Search Agent

Goal-driven **deterministic** agent with

- Perfect knowledge of the world
  - Using **state-based** world representation
  - Environment changes *only* when the agent acts, and in known ways
- Deterministic actions
  - Agent perfectly knows:
    - actions that can be applied in any given state
    - the state it is going to end up in
      when an action is applied in a given state
- Agent is in a start state
- Agent is given a goal (subset of all states)
- A sequence of actions taking the agent
  from the start state to a goal state is a solution (a plan)

Our simple deterministic search agent has …

perfect knowledge of its environment

perfect knowledge of the effect that its actions can have on the environment

Both of the above

None of the above

Definition of a search problem

- State space: set of all possible states
  - Not necessarily given explicitly (state space might be infinite)
- Initial state
- Set of actions (operators) available to the agent: for each state and each operator, if operator applicable, defines **the** successor state: the state the agent would end up in
- Goal state(s): explicit set of states or predicate on states
- Path Cost (we ignore this for now)

Three examples

1. The delivery robot planning the route it will take in a bldg. to get from one room to another (Text: Section 1.6)

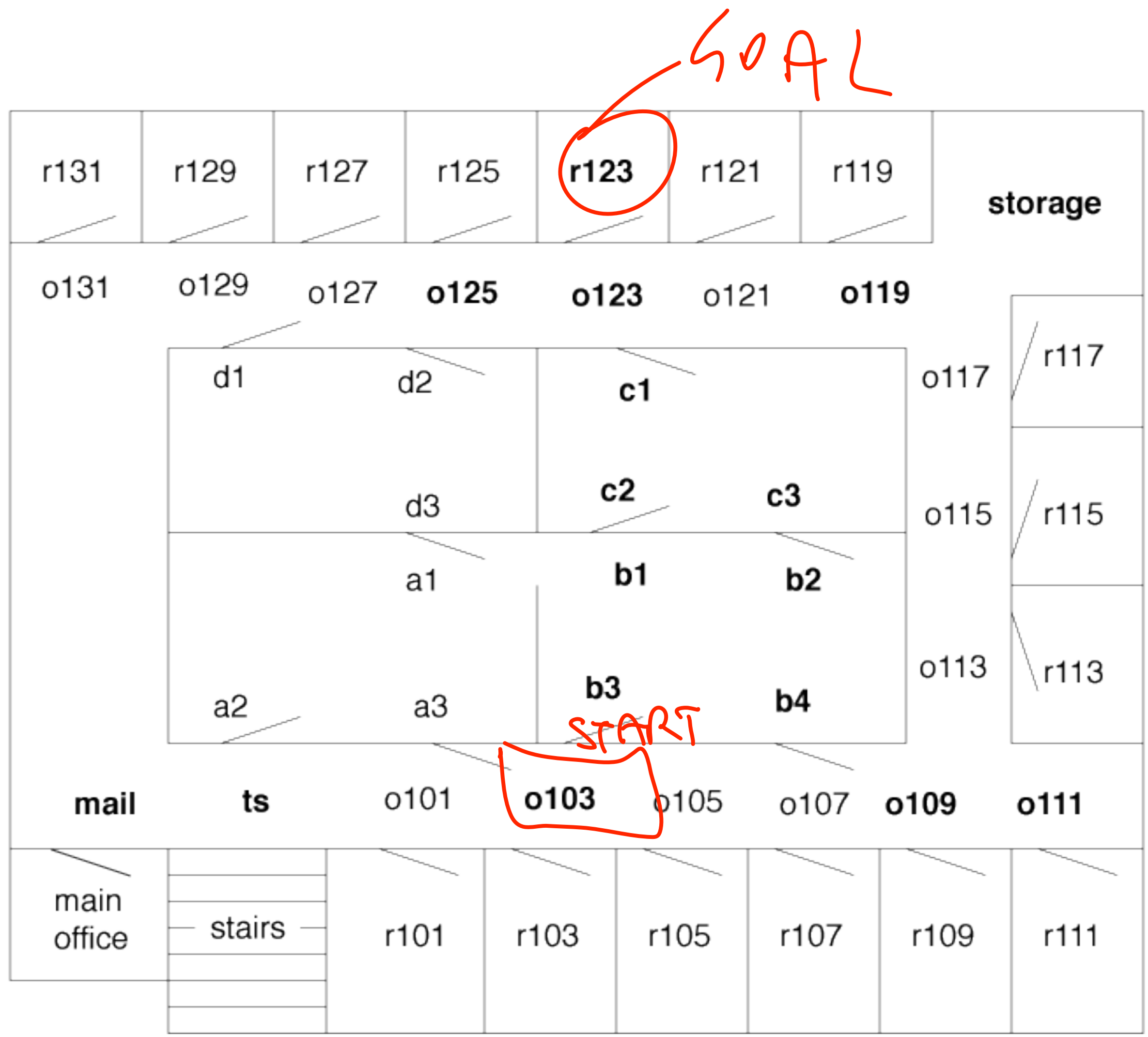
2. Vacuum cleaner world

3. Solving an 8-puzzle

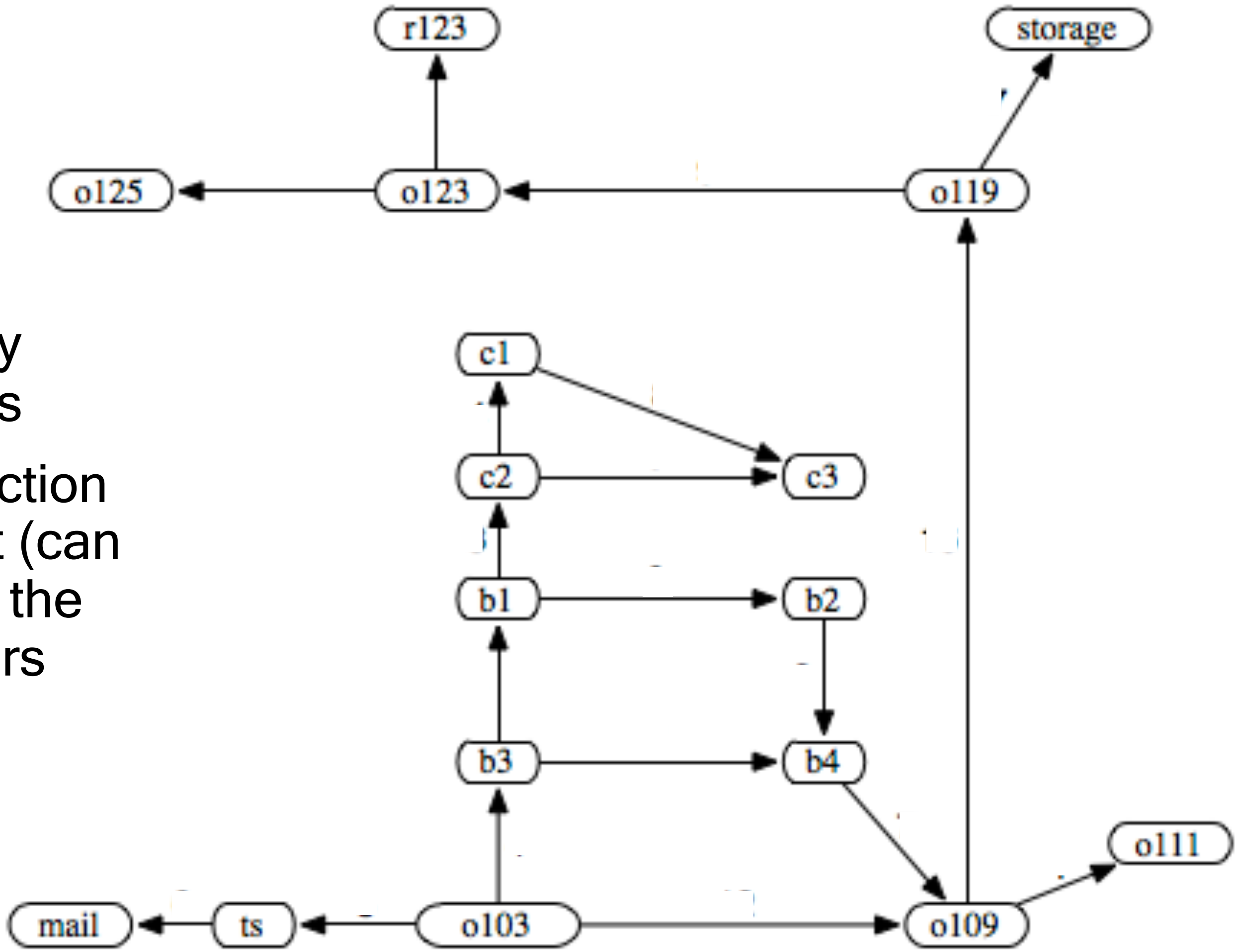
Example 1: Delivery Robot (Ch.1.6)

Simplified

- Consider only bold locations
- Limits in direction of movement (can move only in the direction doors open)
- Start: o103
- Goal: r123



Search Space for the Delivery Robot



Simplified

- Consider only bold locations
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- Start: o103
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Example 2: vacuum world

- States
  - Two rooms: r1, r2
  - Each room can be either dirty or not
  - Vacuuming agent can be in either in r1 or r2

Possible start state

Goal state

Example 2: vacuum world

- States
  - Two rooms: r1, r2
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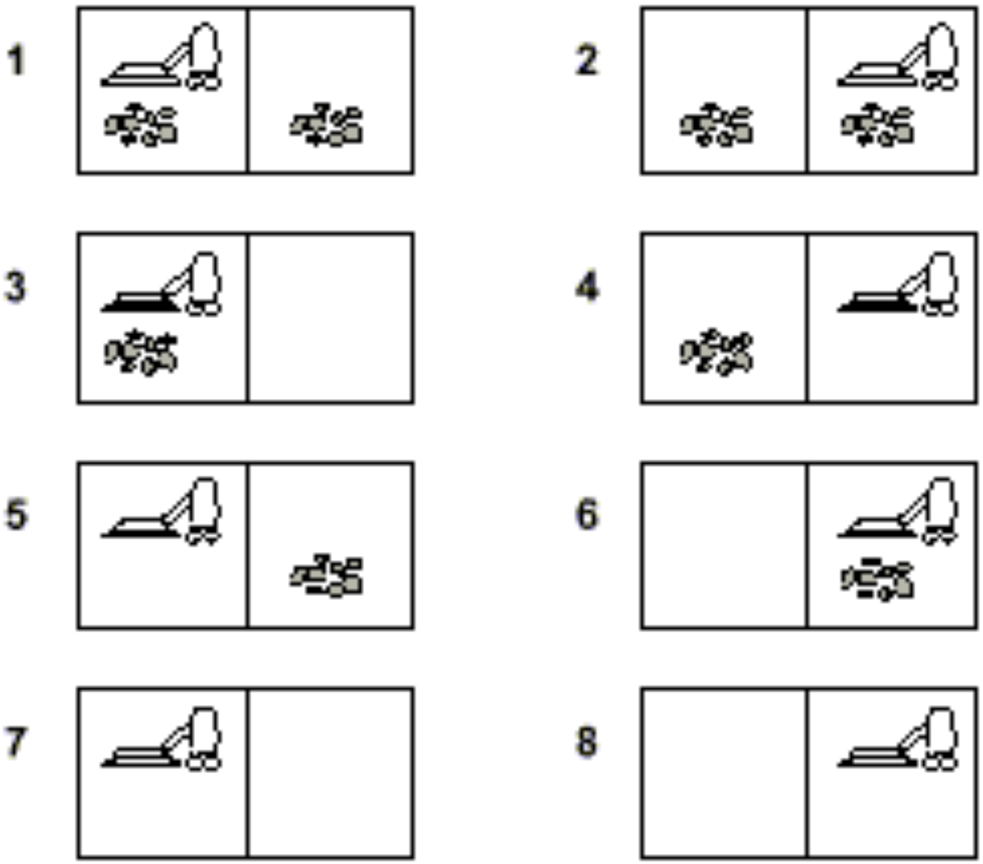
Feature-based representation: how many states?

Possible start state

Goal state

Example 2: vacuum world



- States - one of the eight states in the picture
- Operators -*left, right, suck*
- Possible Goal - no dirt

Suppose we have k rooms instead

- The number of states is then…

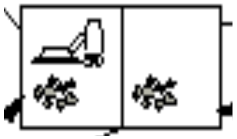
k^3

$k * 2k$

$k * 2^k$

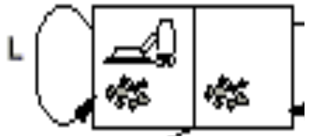
$2 * k^k$

Search Space



- Operators - left, right, suck
  - Successor states in the graph describe the effect of each action applied to a given state
- Possible Goal - no dirt

Search Space



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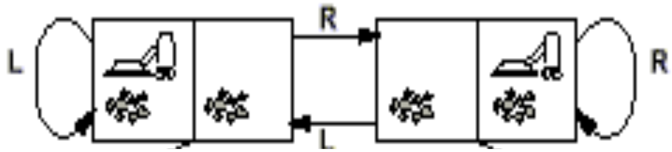

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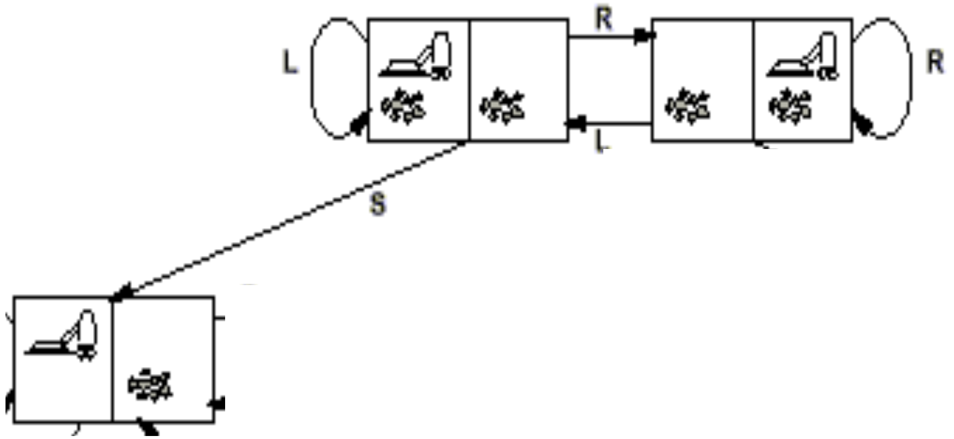

S

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  - Successor states in the graph describe the effect of each action applied to a given state
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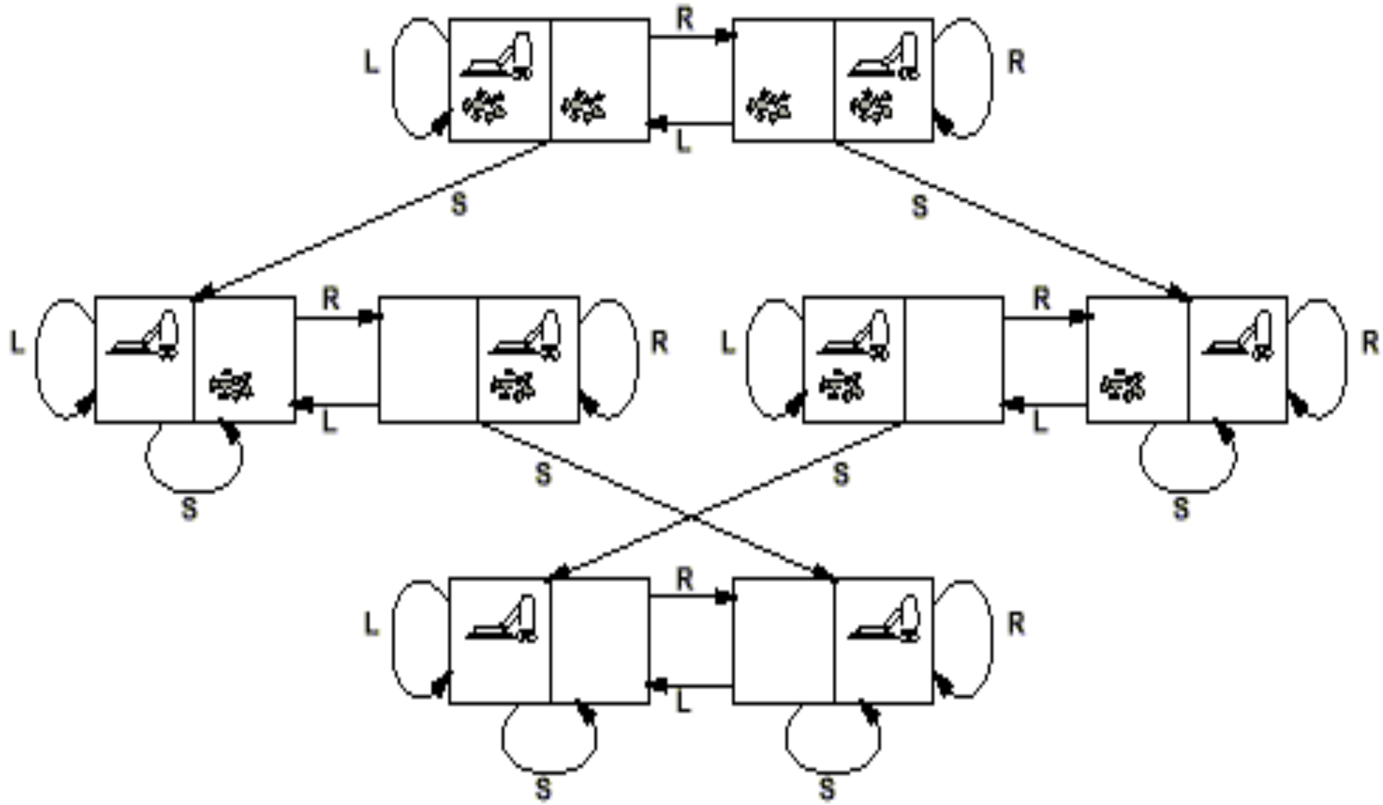
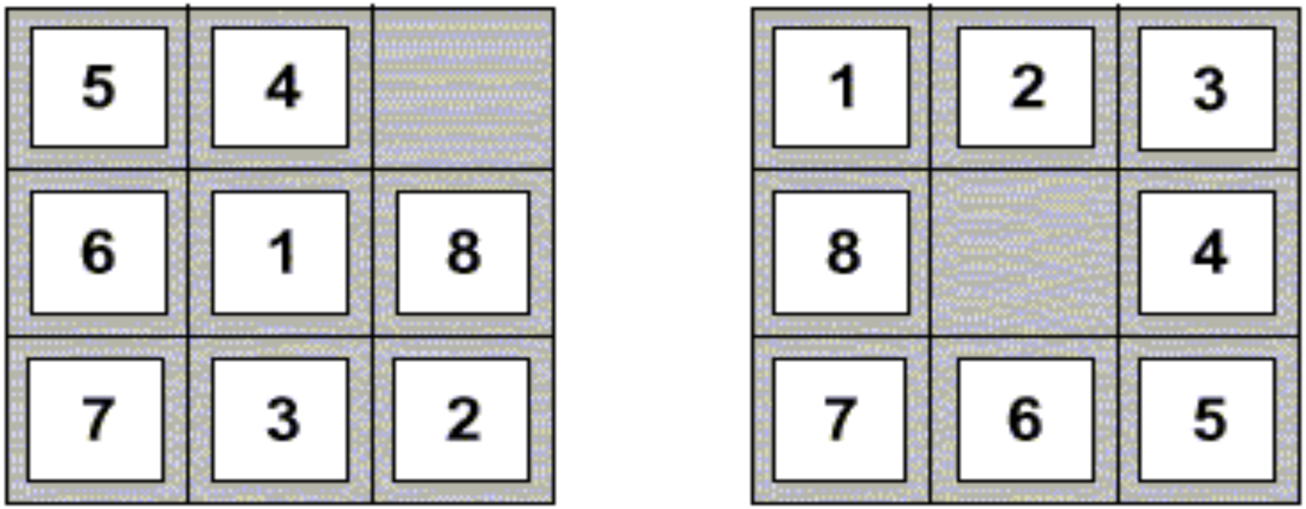
Search Space



- Operators - left, right, suck
  - Successor states in the graph describe the effect of each action applied to a given state
- Possible Goal - no dirt

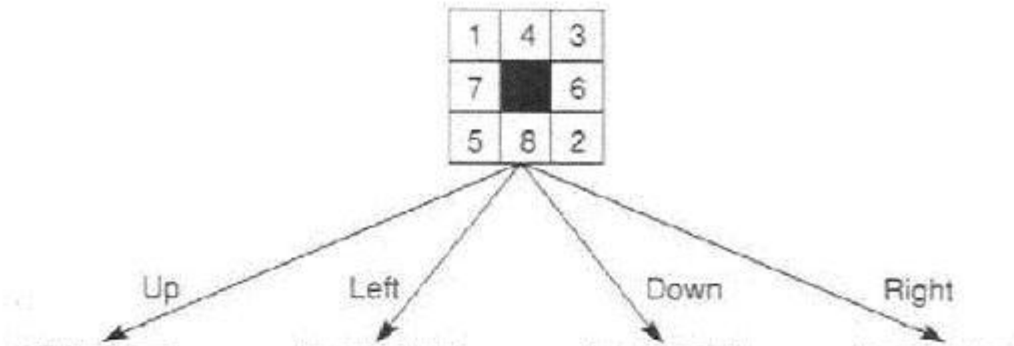
Example 3: 8-Puzzle



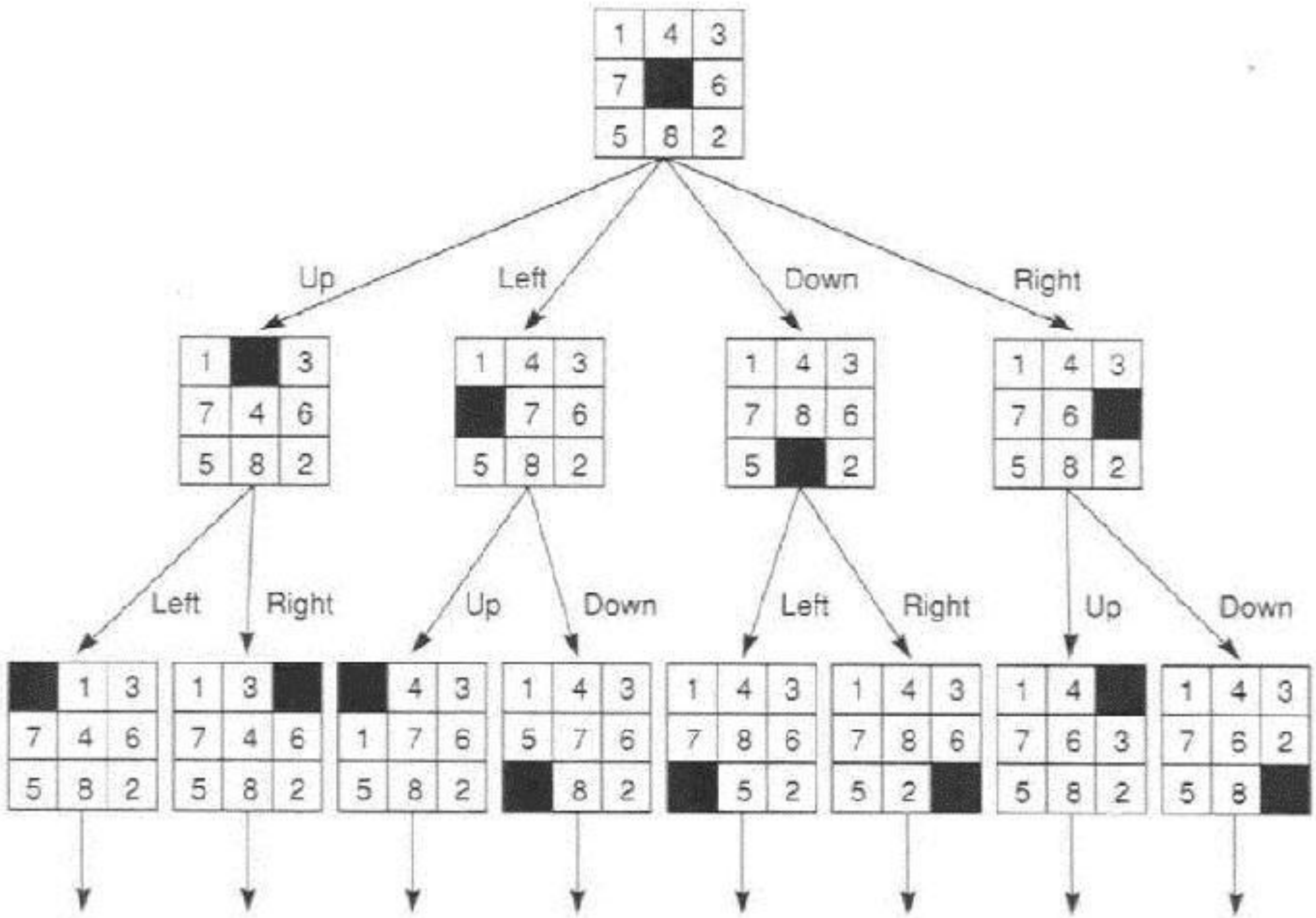
What describes a state?

What are the operators?

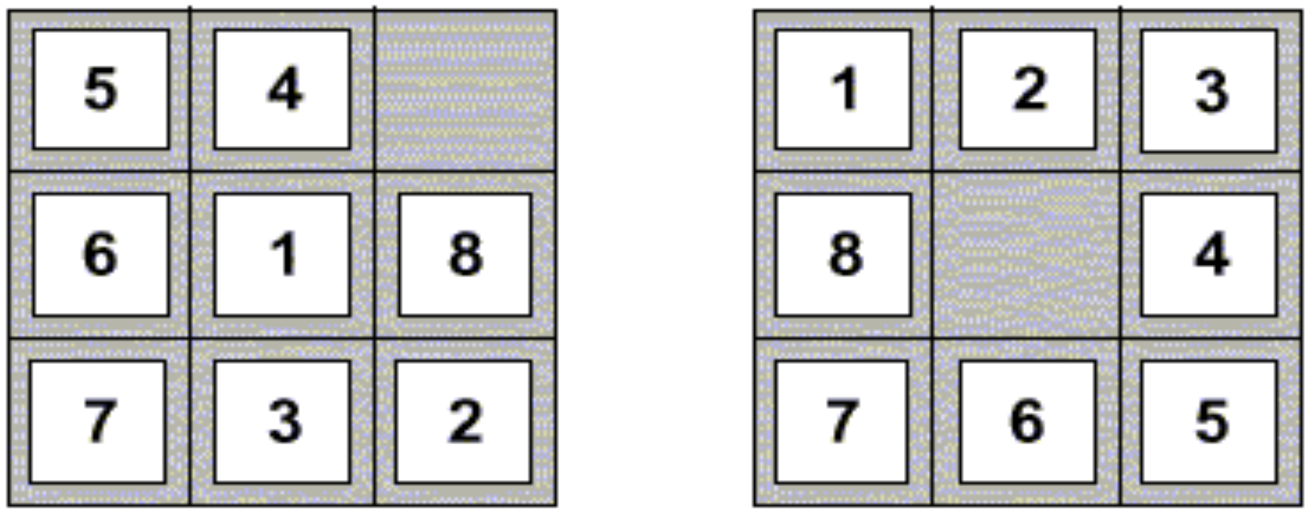
Search space for 8-puzzle



Search space for 8-puzzle



Example 3: Eight Puzzle



Start State Goal State

States: each state specifies which number/blank occupies each of the 9 tiles

- How many states are there? 8^9 2^9 9^9 $9!$

Operators: the blank spot moves left, right, up down

Goal: the configuration with all numbers in the right sequence

Today's Lecture

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- Simple Search Agent and Examples
- General Search Procedure

Search: Abstract Definition

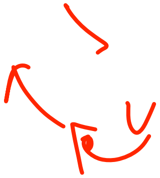
How to search

- Start at the start state
- Evaluate which actions can lead us from states that have been encountered in the search so far to new states
- Stop when a goal state is encountered

To make this more formal, we'll need to review the formal definition of a graph...

Graphs

- A directed graph consists of a set N of nodes (vertices) and a set A of ordered pairs of nodes, called edges (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 $n_0, n_1, .., n_k$ such that $\langle n_{i-1}, n_i \rangle \in A$.
- A cycle is a non-empty path such that the start node is the same as the end node.

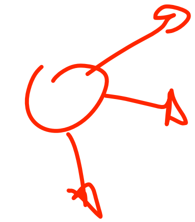


Search graph

- Nodes are search states
- Edges correspond to actions
- Given a set of start nodes and goal nodes, a solution is a path from a start node to a goal node: a plan of actions.

Branching Factor

- The forward branching factor of a node is the number of arcs going out of the node



- The backward branching factor of a node is the number of arcs going into the node

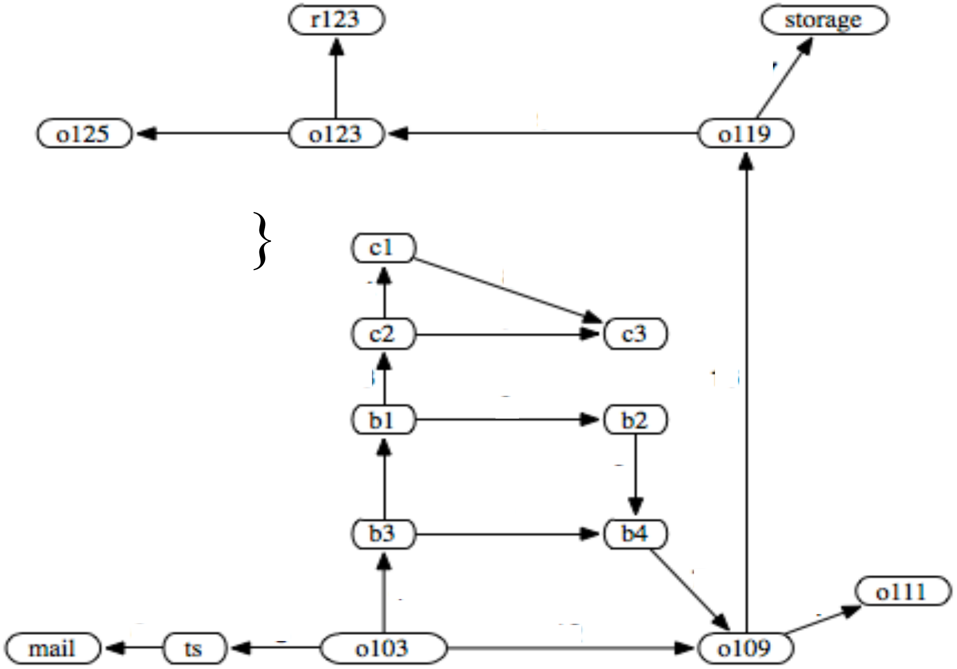
- If the forward branching factor of a node is b
and the graph is a tree,
there are b^n nodes that are n steps away from a node

Graph Specification for the Delivery Robot

Nodes={ }

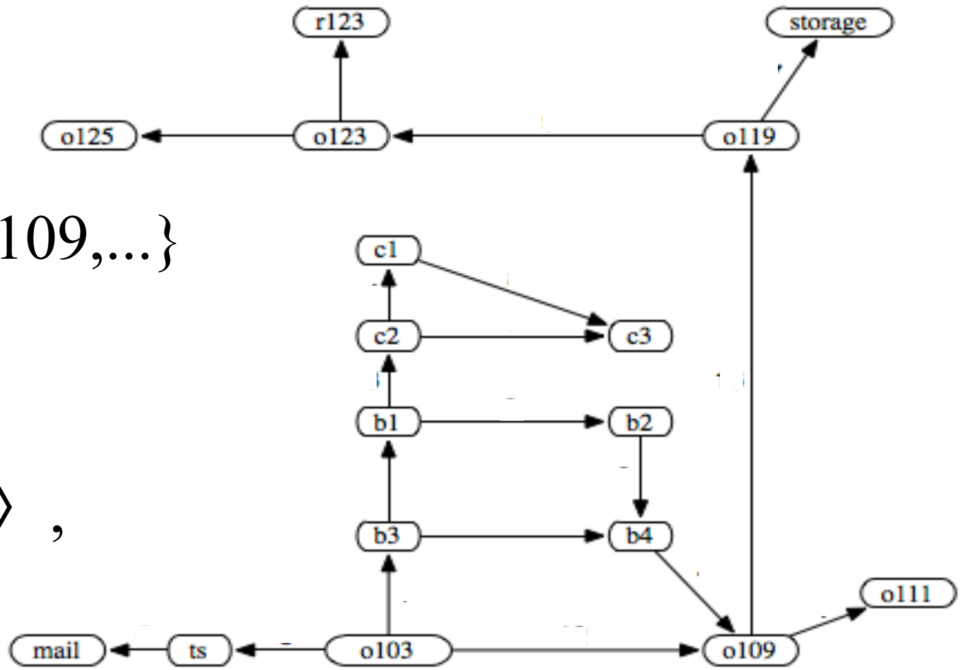
Edges={

...}



Solution paths:

Graph Specification for the Delivery Robot



Nodes={mail, ts, o103, b3, o109,...}

Edges={
⟨ts,mail⟩ ,
⟨o103,ts⟩ , ⟨o103,b3⟩ ,
⟨o103,o109⟩ ,
...}

One of three solution paths:

⟨o103, o109, o119, o123, r123⟩

Graph Searching

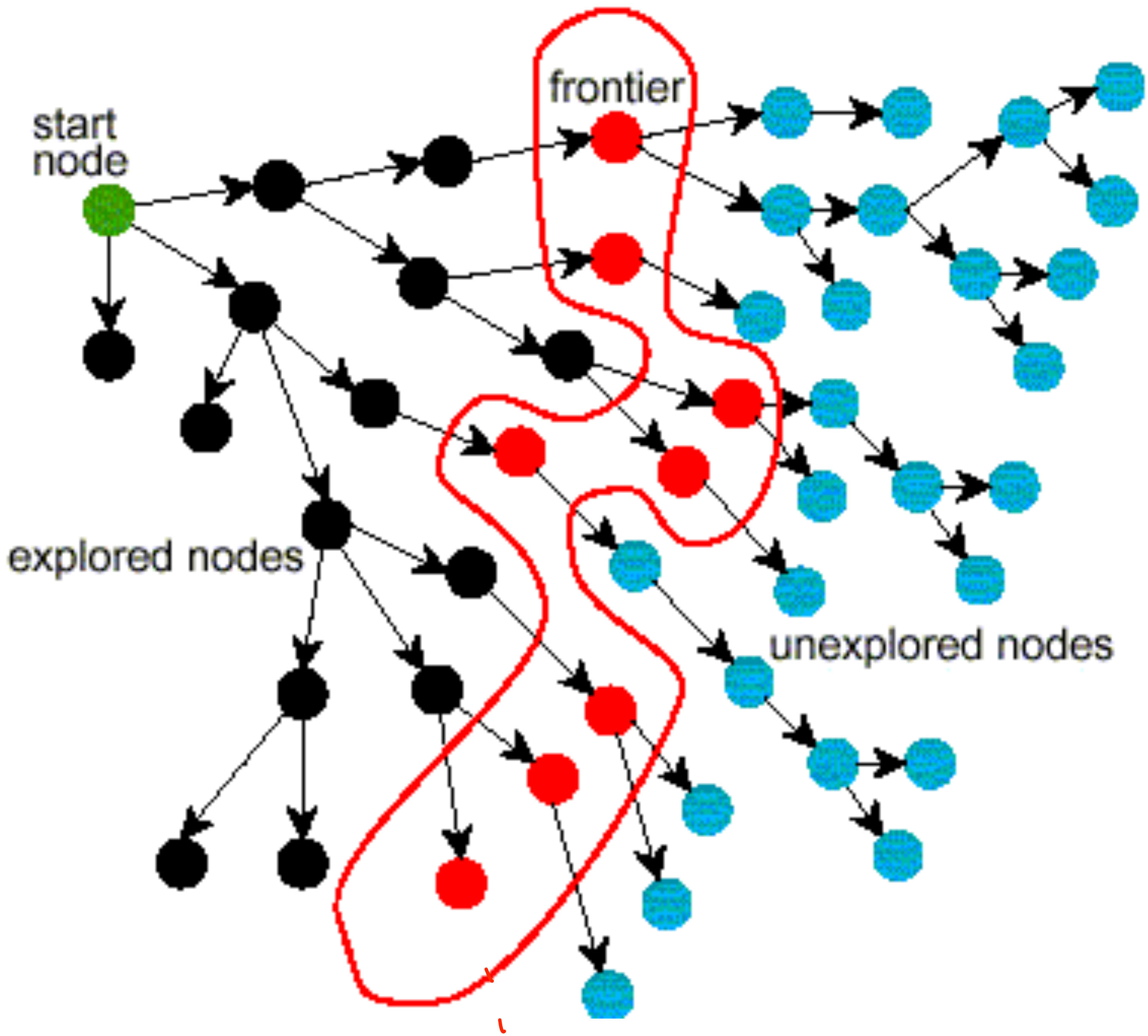
- Generic search algorithm: given a graph, start nodes, and goal nodes, incrementally explore paths from the start nodes

- 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



Generic Search Algorithm

Input: a graph
a set of start nodes
Boolean procedure goal(n) testing if n is a goal node

frontier:= {<s> | s is a start node};
While frontier is not empty:
select and **remove** path $<n_o,\ldots.,n_k>$ from frontier;
If goal(n_k)
Then **return** $<n_o,\ldots.,n_k>$;
Else
For every neighbor n of n_k,
add $<n_o,\ldots.,n_k, n>$ to frontier;
end

Pass out note cards …

Lecture Summary

- Search is a key computational mechanism in many AI agents
- We will study the basic principles of search on the simple deterministic goal-driven search agent model in state-based world representation

- Generic search approach:
  - Define a search space graph
  - Initialize the frontier with an empty path
  - incrementally expand frontier until goal state is reached

- The way in which the frontier is expanded defines the search strategy

Learning Goals for today's class

- **Identify** real world examples that make use of deterministic goal-driven search agents
- **Assess** the size of the search space of a given search problem
- **Implement** the generic solution to a search problem

Coming up:

- Uninformed search: read section 3.5

Note cards

- Brief, informal feedback on teaching
- This is your chance to influence how I teach the course

- Front: What do you like?
  - I.e., what would you like me to continue doing?

- Back: What do you not like?
  - I.e., what would you like me to stop doing (or start doing instead) ?