Search: Intro

Computer Science cpsc322, Lecture 4

(Textbook Chpt 3.0-3.4)

May 18, 2017

Announcements

- Still looking for rooms for some TAs office hours (stay tuned)
- Straw Poll for break length

  A 15min

  B 20min

  C 25min
- Assignment 1 will be out by Tue (on Search)

People

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Modules we'll cover in this course: R&Rsys

First part of the course

Environment

Problem		Deterministic	Stochastic
Static	Constraint Satisfaction	*Vars + Constraints* Arc Consistency Search	
Static	Query	*Logics* Search	*Belief Nets* Var. Elimination
Sequential	Planning	*STRIPS* Search	*Decision Nets* Var. Elimination *Markov Processes* Value Iteration

Representation

Reasoning Technique

Lecture Overview

- **Simple Agent and Examples**
- Search Space Graph
- Search Procedure

Simple Planning Agent

Deterministic, goal-driven agent

- Agent is in a **start state**
- Agent is given a **goal** (subset of possible states)
- Environment changes only when the agent acts
- Agent perfectly knows:
  - **what actions 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

- The sequence of actions and their appropriate ordering is the **solution**

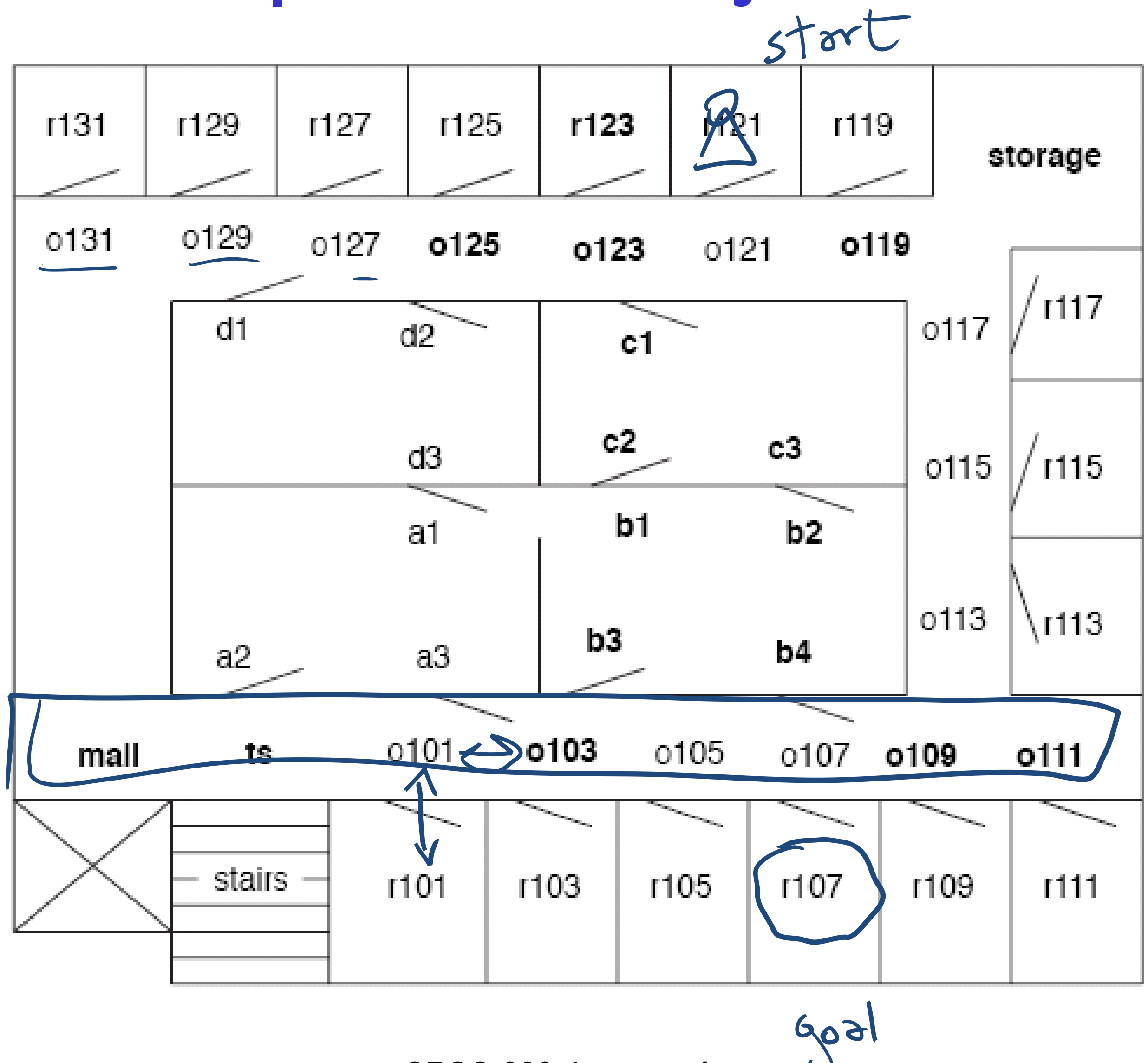
Three examples

1. A delivery robot planning the route it will take in a bldg. to get from one room to another

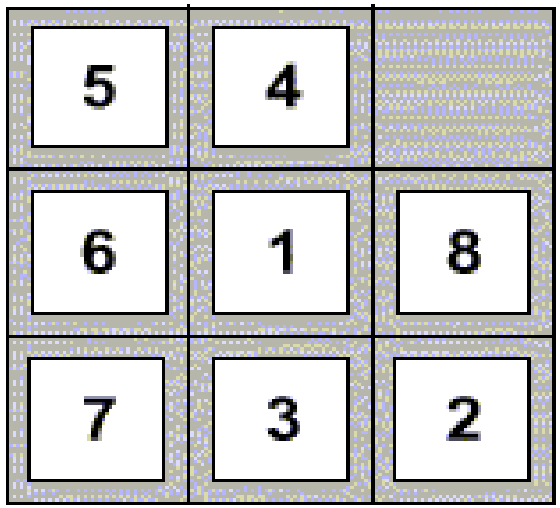
2. Solving an 8-puzzle

3. Vacuum cleaner world

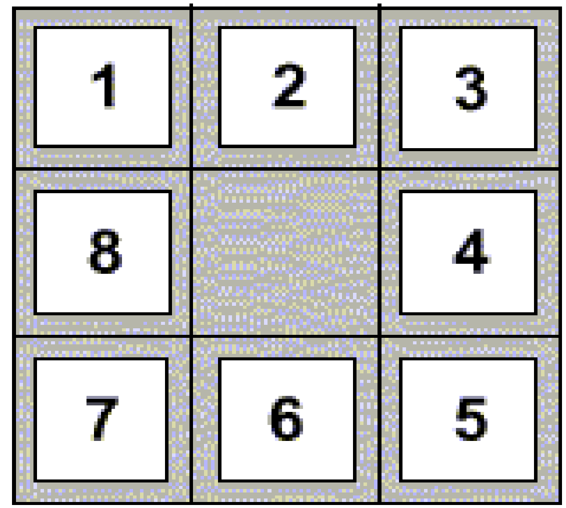
Example1: Delivery Robot



Eight Puzzle



Start State



Goal State

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

HOW MANY STATES ?

8^9 2^9 9^9 $9!$

Actions: blank moves left, right, up down

Possible Goal: configuration with numbers in right sequence

Example 2: 8-Puzzle?

\# of states

$9!$

$\sim 360 \times 10^3$

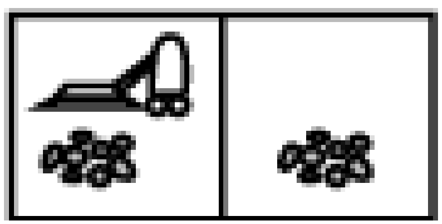
Possible start state

Goal state

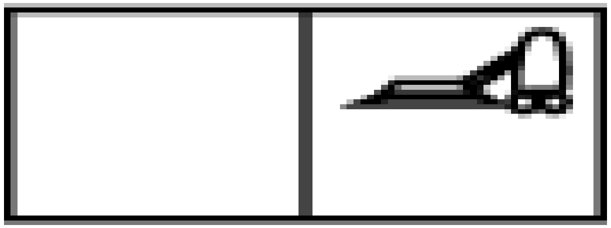
Example: vacuum world

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



Possible goal state

Example: vacuum world

loc 2 values $\{r_1, r_2\}$

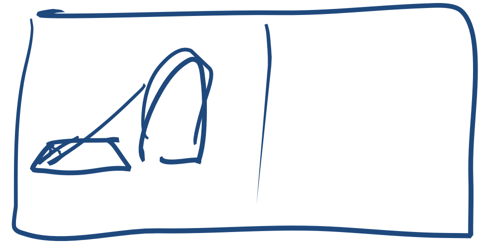
r1-clean T/F

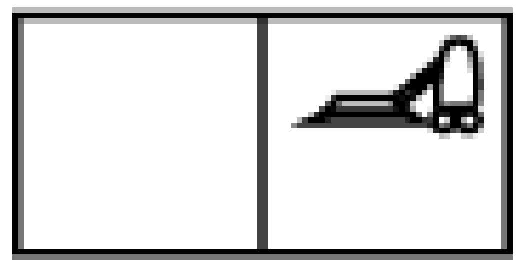
r2-clean

Possible start state

\# of states

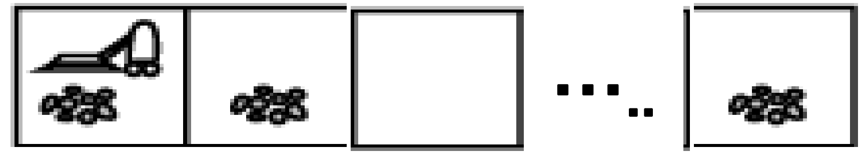
$2\,2^2$





Goal state

can be subset of states



Suppose we have the same problem with *k* rooms.

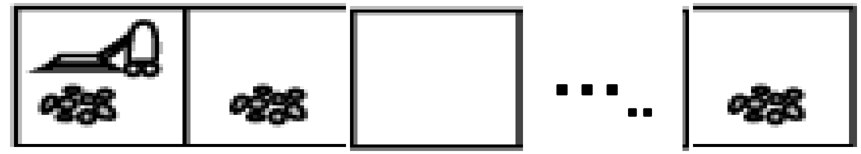
The number of states is⋯.

k^3

$k * 2k$

$k * 2^k$

$2 * k^k$



Suppose we have the same problem with *k* rooms.

The number of states is···.

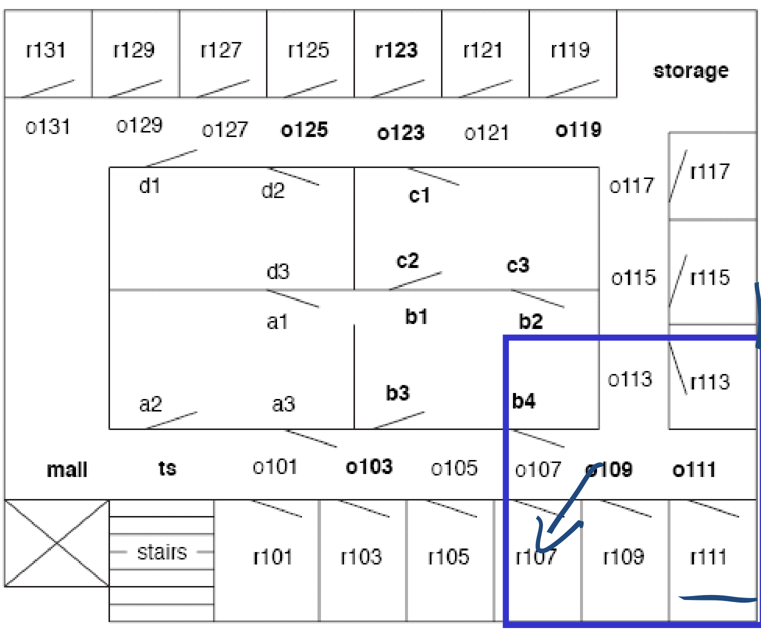
$k * 2^k$

Lecture Overview

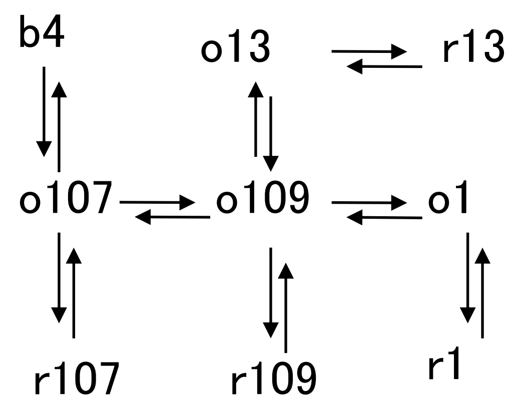
- Simple Agent and Examples
- Search Space Graph
- Search

How can we find a solution?

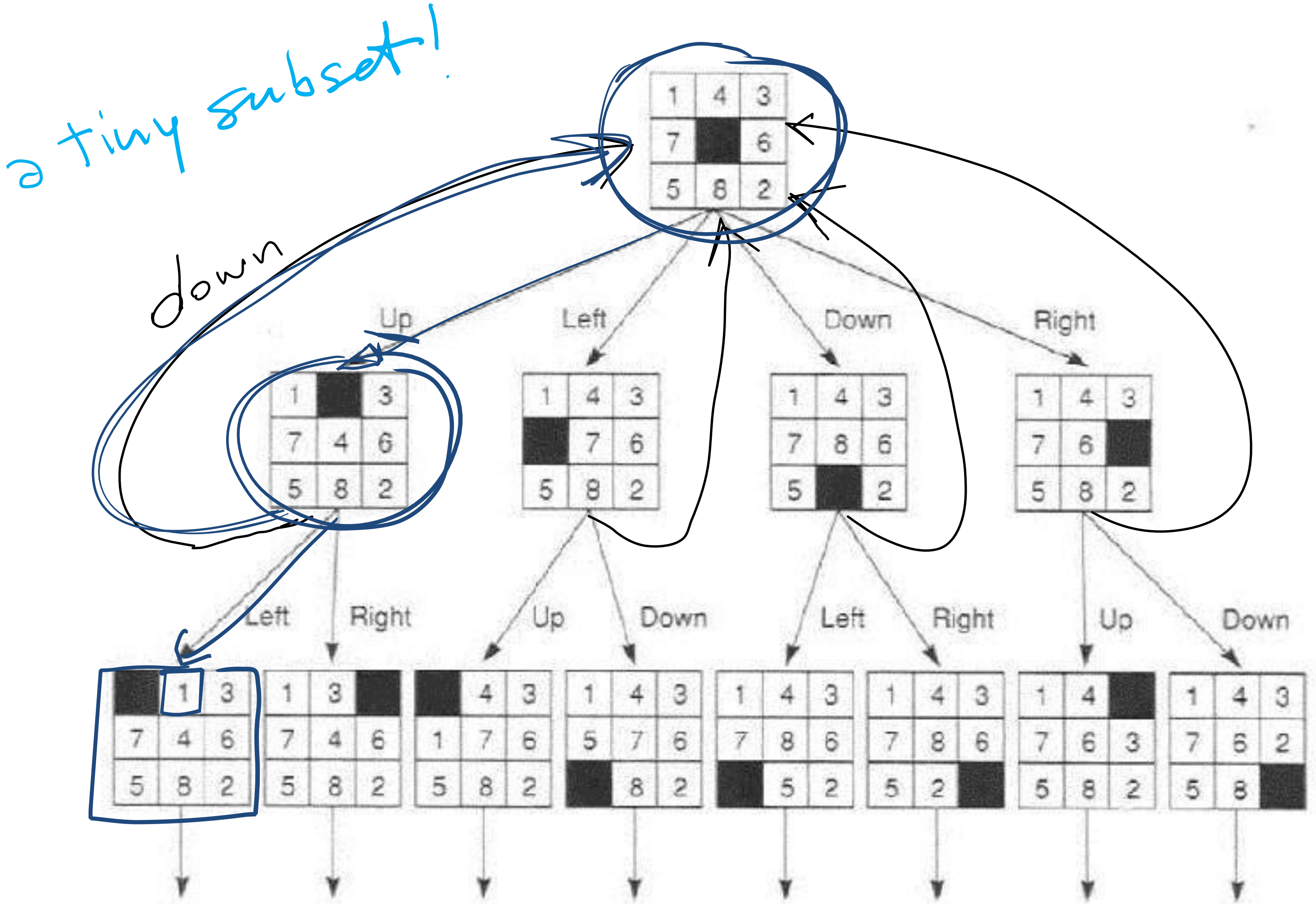
- How can we find a sequence of actions and their appropriate ordering that lead to the goal?
- Define underlying **search space graph** where **nodes are states** and **edges are actions**.



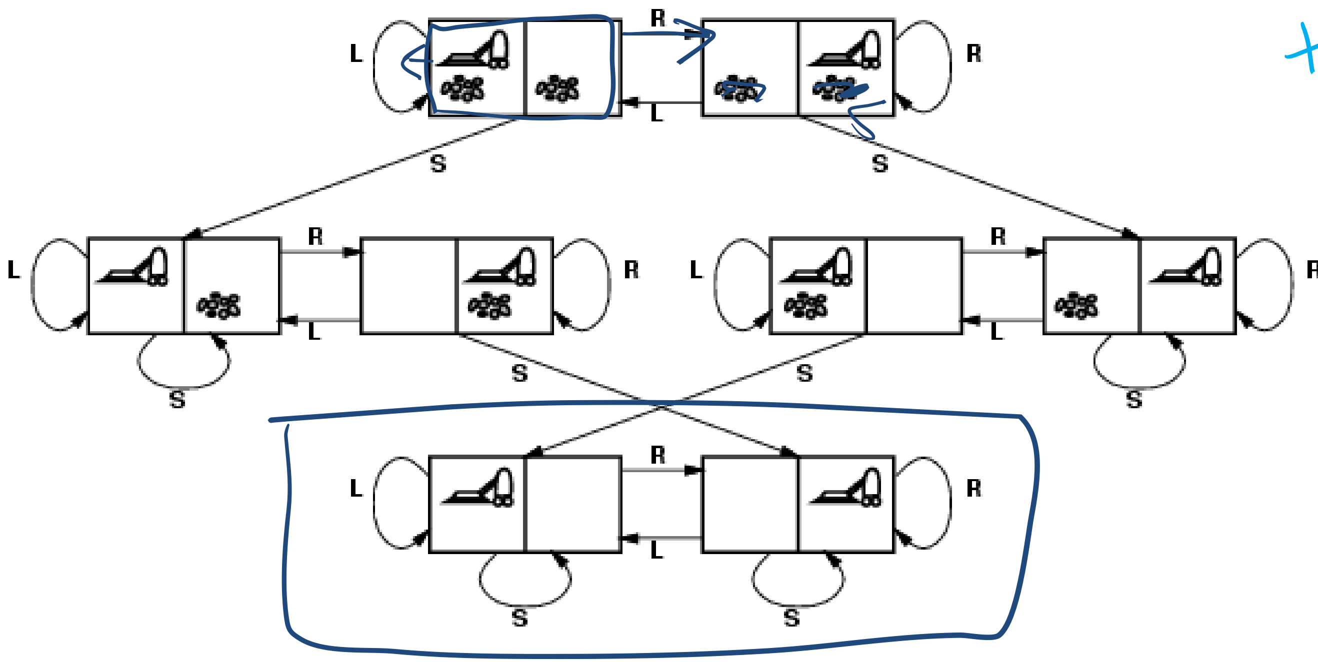
only for this subset



Search space for 8puzzle



Vacuum world: Search space graph



the whole
space

states? Where it is dirty and robot location

actions? *Left, Right, Suck*

Possible goal test? no dirt at all locations

Lecture Overview

- Simple Agent and Examples
- State Space Graph
- **Search Procedure**

Search: Abstract Definition

How to search

- Start at the start state
- Consider the effect of taking different actions starting from states that have been encountered in the search so far
- Stop when a goal state is encountered

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

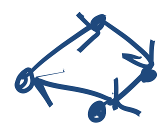
Search Graph

A ***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 $n_0, n_1, n_2, \ldots, n_k$ 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



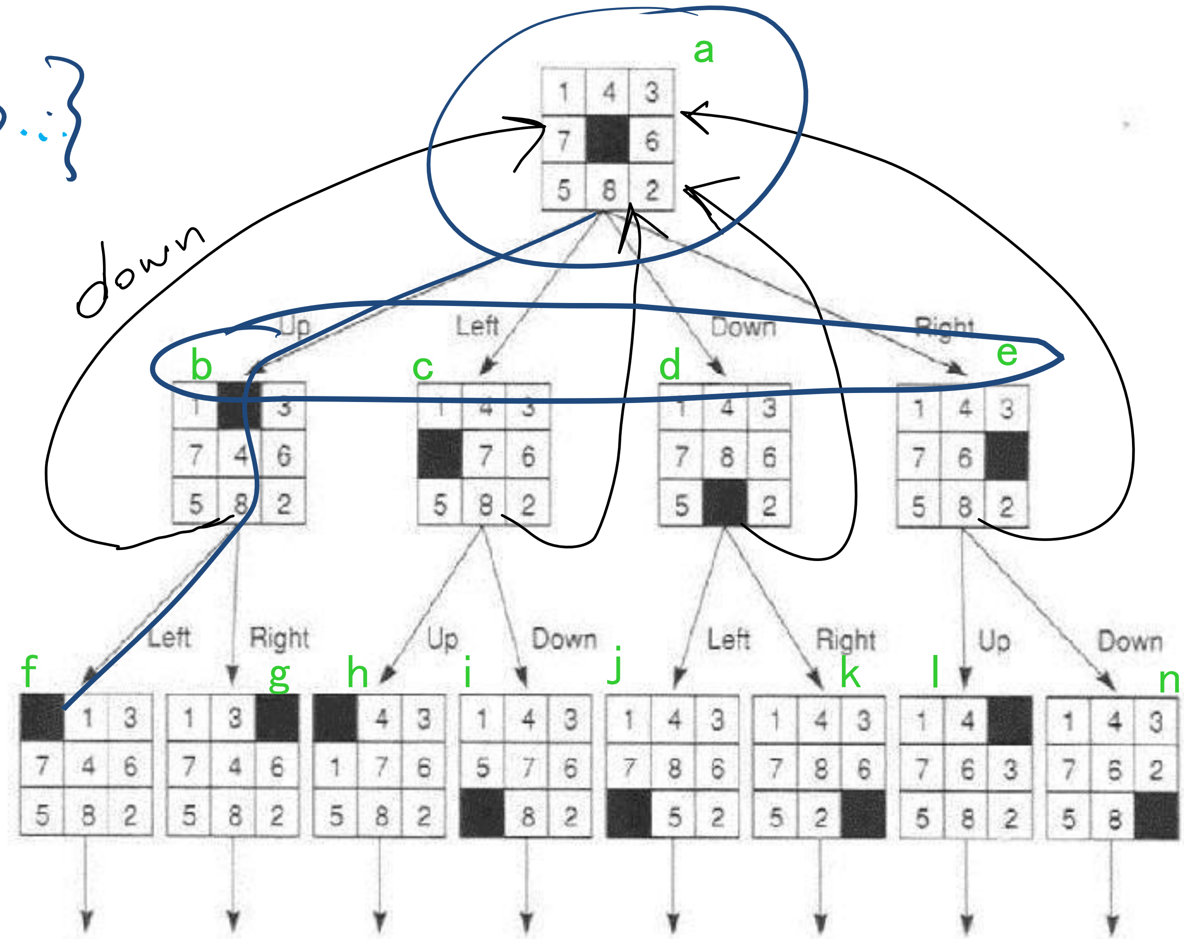
A ***directed acyclic graph*** (DAG) is a graph with no cycles

Given a start node and goal nodes, a ***solution*** is a path from a start node to a goal node.

Examples for graph formal def.

$N = \{a\ b \ldots\}$

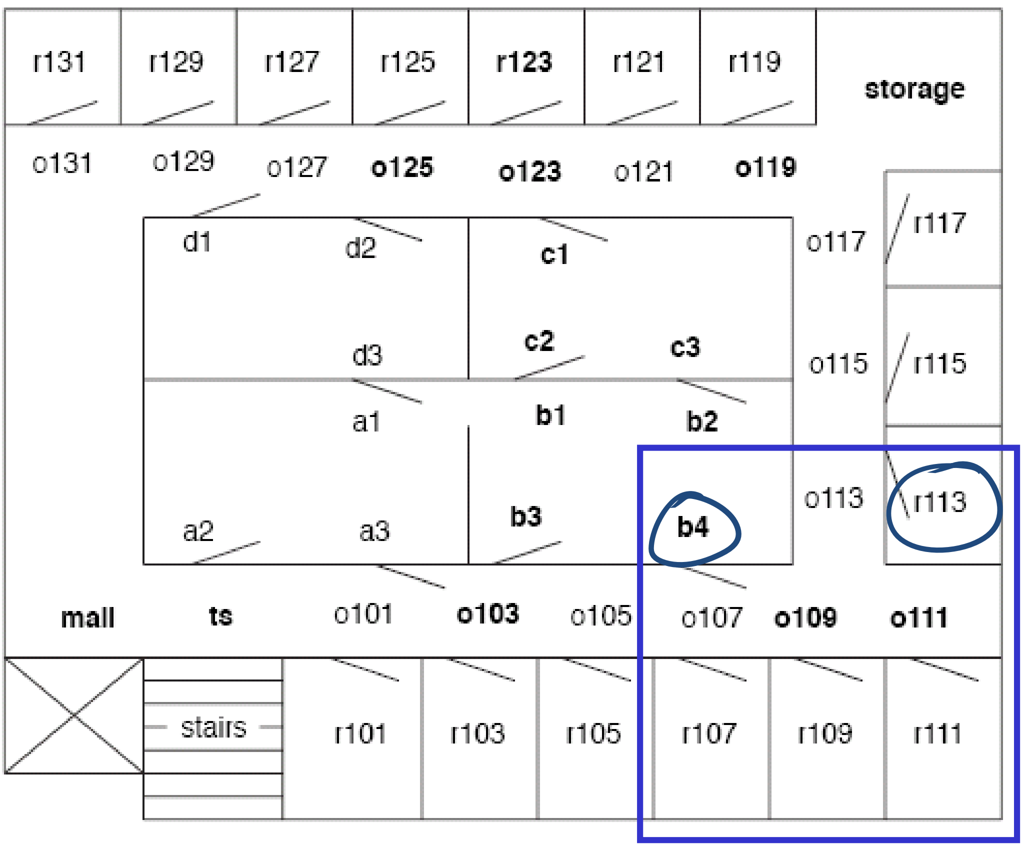
$A = \{\langle a,b\rangle \langle a,c\rangle \ldots\}$

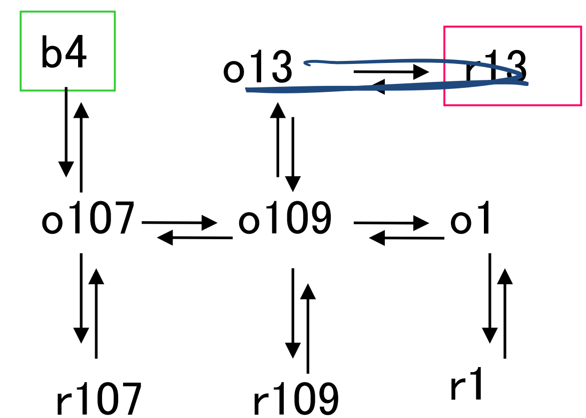


Examples of solution

- Start state b4, goal r13
- Solution ⟨b4, o107, o109, o13, r13⟩

but there are many others!





Graph Searching

Generic search algorithm: given a graph, start node, and goal node(s), incrementally explore paths from the start node(s).

Maintain a **frontier of paths** from the start node that have been explored.

As search proceeds, the frontier expands into the unexplored nodes until (hopefully!) a goal node is encountered.

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

IMPLICIT IN PRACTICE

Generic Search Algorithm

Input: a graph, a start node n_o, Boolean procedure *goal(n)* that tests if n is a goal node

frontier := [⟨*s*⟩: *s* is a start node];

While *frontier* is not empty:

  select and **remove** path $\langle n_o, \cdots, n_k \rangle$ from *frontier;*

  If *goal*(n_k)

    return $\langle n_o, \cdots, n_k \rangle$;

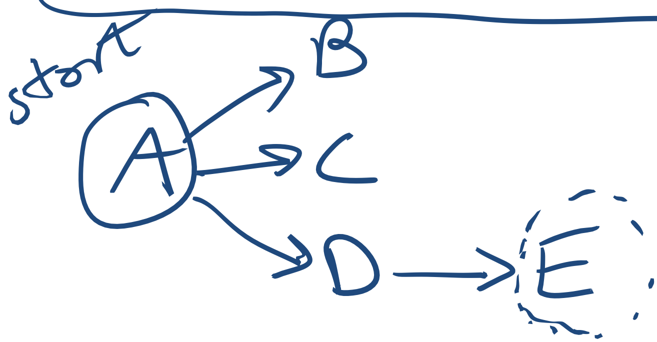
  For every neighbor n of n_k

    add $\langle n_o, \cdots, n_k, n \rangle$ to *frontier;*

end

no solution found

with cycles may get into infinite loop



goal(E) = T

Frontier

~~⟨A⟩~~

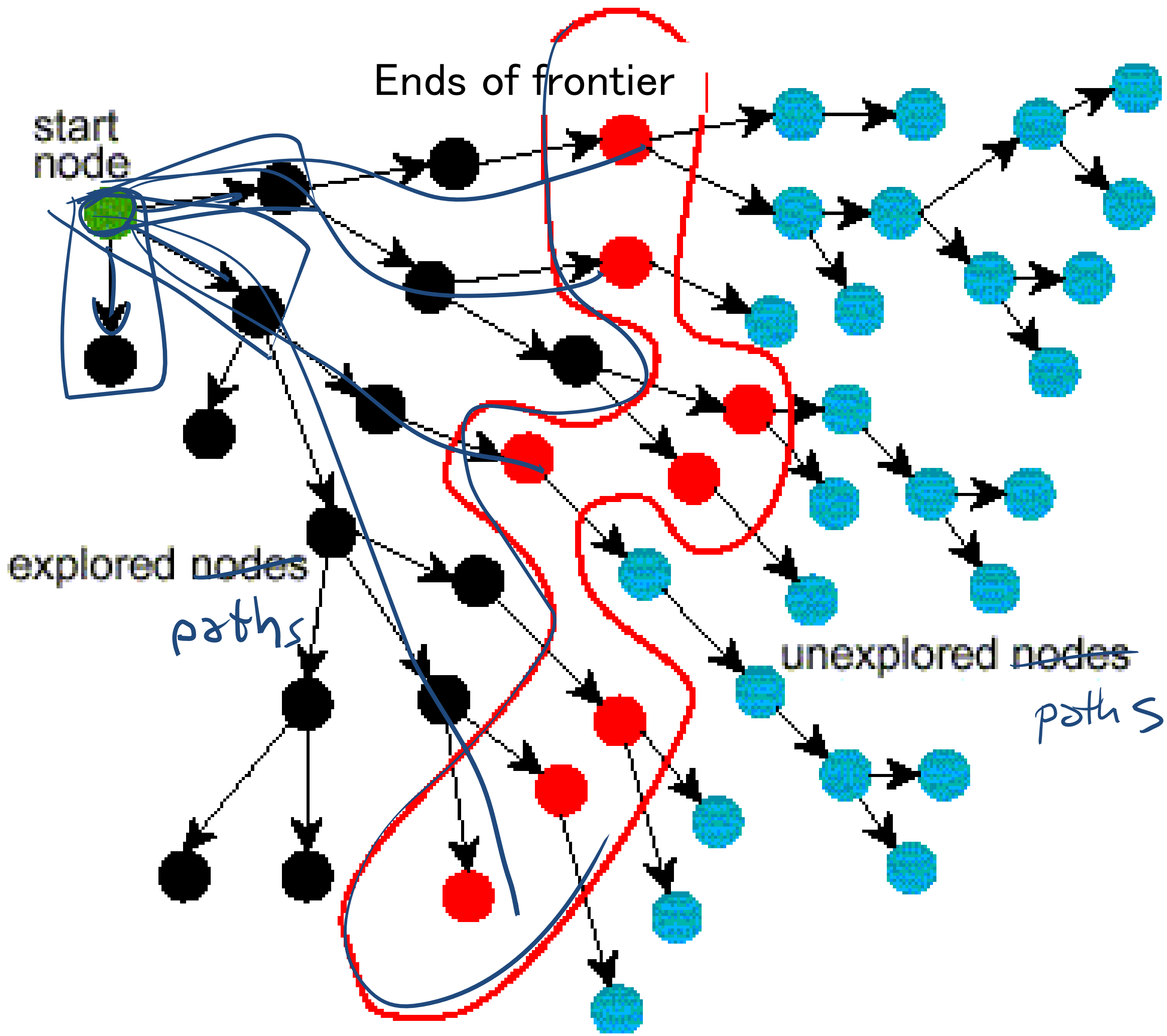
~~⟨A B⟩~~

~~⟨A C⟩~~

~~⟨A D⟩~~

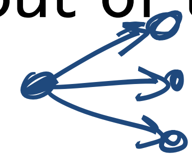
$\boxed{\langle A\ D\ E \rangle}$

Problem Solving by Graph Searching



Branching Factor

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



3

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

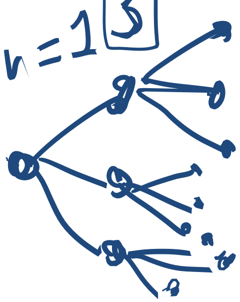
4

If the forward branching factor of any node is b and the graph is a tree, how many nodes are n steps away from a node?

iclicker

$b=3$

$n=1$ $\boxed{3}$



$n=2$ $\boxed{9}$

$=3^n$

nb	b^n	n^b	n/b

Lecture Summary

- Search is a key computational mechanism in many AI agents
- We will study the basic principles of search on the simple **deterministic planning agent model**

Generic search approach:

- define a search space graph,
- start from current state,
- incrementally explore paths from current state 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 planning agents
- **Assess** the size of the search space of a given search problem.

  How many possible states

- **Implement** the generic solution to a search problem.

  see also Mars Explorer Lecture 2

Next class

- **Uninformed search** strategies

(read textbook Sec. 3.5)

- First **Practice Exercise** 3.A
- http://www.aispace.org/exercises.shtml