Intelligent Agents

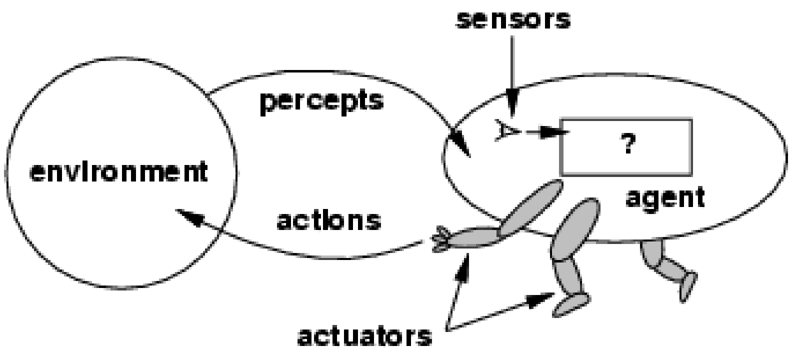
AIMA, Chapter 2.1-2.2

Outline for today's lecture

- ***Intelligent Agents (AIMA 2.1-2)***
- **Task Environments**

- **Formulating Search Problems**
- **Search Fundamentals (if time)**

Agents and environments



- **An agent is specified by an *agent function*** $f{:}P \rightarrow a$ **that maps a sequence of percept vectors** P **to an action** a **from a set** A**:**

$$P=[\boldsymbol{p}_0, \boldsymbol{p}_1, \ \dots\ , \boldsymbol{p}_t]$$

$$A=\{a_0, a_1, \ \dots\ , a_k\}$$

Agents

- **An *agent* is anything that can be viewed as**
  - *perceiving* its *environment* through *sensors* and
  - *acting* upon that environment through *actuators*

- **Human agent:**
  - Sensors: eyes, ears, ...
  - Actuators: hands, legs, mouth, …

- **Robotic agent:**
  - Sensors: cameras and infrared range finders
  - Actuators: various motors

- **Agents include humans, robots, softbots, thermostats, …**

Agent function & program

- **The *agent program* runs on the physical *architecture* to produce** f
  - *agent = architecture + program*
- **"Easy" solution: table that maps every possible sequence** P **to an action** a
  - One small problem: exponential in length of P

Rational agents II

- **Rational Agent: For each possible percept sequence *P*, a rational agent should select an action *a* that is *expected* to *maximize* its *performance measure*.**
- **Performance measure: An objective criterion for success of an agent's behavior, given the evidence provided by the percept sequence.**
- **A performance measure for a vacuum-cleaner agent might include e.g. some subset of:**
  - +1 point for each clean square in time T
  - +1 point for clean square, -1 for each move
  - -1000 for more than *k* dirty squares

Rationality is *not* omniscience

- **Ideal agent: maximizes *actual* performance, but needs to be *omniscient.***
  - Usually impossible…..
    - — But consider tic-tac-toe agent…
  - Rationality ≠ Guaranteed Success

- **Caveat: computational limitations make *perfect rationality* unachievable**

  →design best *program* for given machine resources

- **In Economics:**
  "Bounded Rationality" → "Behavioral Economics

Outline for today's lecture

- **Intelligent Agents**
- ***Task Environments (AIMA 2.3)***
- **Formulating Search Problems**
- **(Search Fundamentals)**

Task environments

- **To design a rational agent we need to specify a *task environment***
  - a problem specification for which the agent is a solution

- ***PEAS:*** *to* specify a task environment
  - ***P***erformance measure
  - ***E***nvironment
  - ***A***ctuators
  - ***S***ensors

PEAS: Specifying an automated taxi driver

Performance measure**:**

- ?

Environment**:**

- ?

Actuators**:**

- ?

Sensors**:**

- ?

PEAS: Specifying an automated taxi driver

***P**erformance measure:*

- safe, fast, legal, comfortable, maximize profits

***E**nvironment:*

- roads, other traffic, pedestrians, customers

***A**ctuators:*

- steering, accelerator, brake, signal, horn

***S**ensors:*

- cameras, sonar, speedometer, GPS

PEAS: Medical diagnosis system

- ***P****erformance measure*: Healthy patient, minimize costs, lawsuits
- ***E****nvironment*: Patient, hospital, staff
- ***A****ctuators*: Screen display (form including: questions, tests, diagnoses, treatments, referrals)
- ***S****ensors*: Keyboard (entry of symptoms, findings, patient's answers)

The rational agent designer's goal

- **Goal of AI practitioner who designs rational agents: given a *PEAS* task environment,**

  1. **Construct agent function *f* that maximizes (the expected value of) the performance measure,**

  2. **Design an agent program that implements *f* on a particular architecture**

Environment types: Definitions I

- ***Fully observable*** **(vs. partially observable): An agent's sensors give it access to the complete state of the environment at each point in time.**

- ***Deterministic*** **(vs. stochastic): The next state of the environment is completely determined by the current state and the action executed by the agent.**
  - If the environment is deterministic except for the actions of other agents, then the environment is *strategic*.

- ***Episodic*** **(vs. sequential): The agent's experience is divided into atomic "episodes" during which the agent perceives and then performs a single action, and the choice of action in each episode depends only on the episode itself.**

Environment types: Definitions II

- ***Static*** **(vs. dynamic): The environment is unchanged while an agent is deliberating.**
  - The environment is *semidynamic* if the environment itself does not change with the passage of time but the agent's performance score does.

- ***Discrete*** **(vs. continuous): A limited number of distinct, clearly defined percepts and actions.**

- ***Single agent*** **(vs. multiagent): An agent operating by itself in an environment.**

(See examples in AIMA, however I don't agree with some of the judgments)

Environment Restrictions for Now

- **We will assume environment is**
  - ***Static***
  - ***Fully Observable***
  - ***Deterministic***
  - ***Discrete***

Problem Solving Agents & Problem Formulation

AIMA 2, 3.1-3

Outline for today's lecture

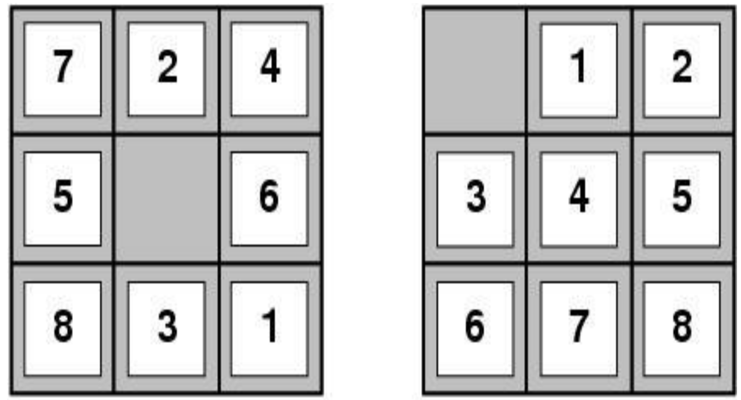
- **Intelligent Agents**
- **Task Environments**
- ***Formulating Search Problems (AIMA, 3.1-3.2)***
- **(Search Fundamentals)**

Two Approaches to AI

- ***Logical representations (Modules 1&3)***
  - *Dominant BEFORE 1995*
  - Relations between entities
    - "Mitch's bicycle is red"
      - (isa B3241 bicycle) (color B3231 red) (owns B3241 P119)
      - (isa P119 person) (name P119 "Mitch")
  - Explicit logical models
  - Search (module 1), Logical inference (module 3)
  - Chess, Sudoko, computer games, …
- ***Statistical models (Module 2)***
  - *Dominant SINCE 2000*
  - Prediction by look-up or by weighted combinations
    - $P(y=\text{bicycle}) = c_0 + c_1 x_1 + c_2 x_2 + c_3 x_3 + \ldots$
  - Machine Learning, Machine vision, speech recognition, …

Example search problem: 8-puzzle

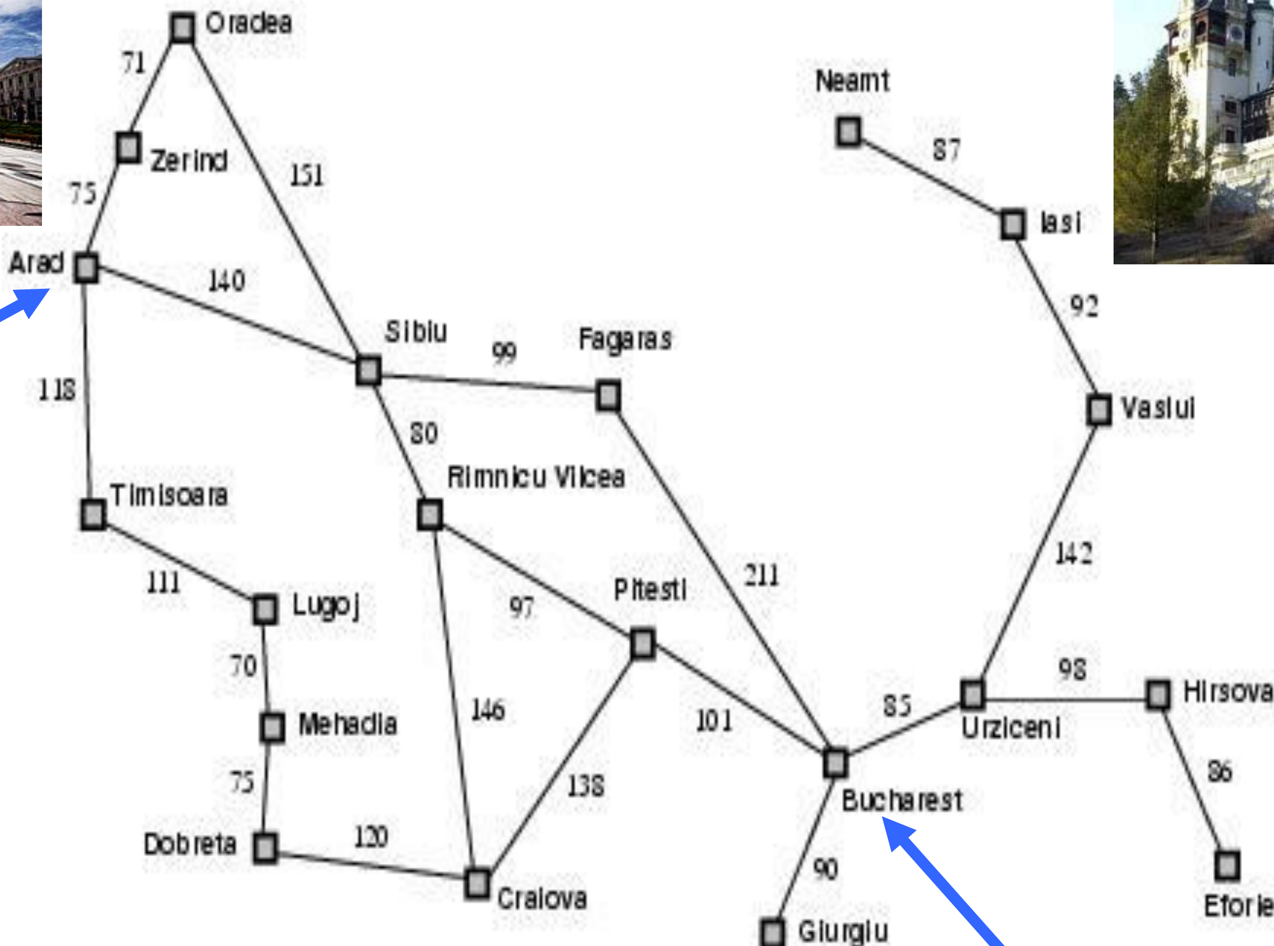
- **Formulate *goal***
  - Pieces to end up in order as shown…



Start State Goal State

- **Formulate *search problem***
  - ***States:*** configurations of the puzzle (9! configurations)
  - ***Actions***: Move one of the movable pieces (≤4 possible)
  - ***Performance measure***: minimize total moves
- **Find *solution***
  - Sequence of pieces moved: 3,1,6,3,1,…

Example search problem: holiday in Romania



You are here

You need to be here

Holiday in Romania II

- **On holiday in Romania; currently in Arad**
  - Flight leaves tomorrow from Bucharest
- **Formulate *goal***
  - Be in Bucharest
- **Formulate *search problem***
  - States: various cities
  - Actions: drive between cities
  - Performance measure: minimize distance
- **Find *solution***
  - Sequence of cities; e.g. Arad, Sibiu, Fagaras, Bucharest, …

More formally, a problem is defined by:

Formulate Search Problem

1. States: a set S
2. *An initial state* $s_i \in S$
3. *Actions: a set* A
   - $\forall s$ $Actions(s)$ = *the set of actions that can be executed in* s, *that are applicable* in s.
4. *Transition Model:* $\forall s \forall a \in Actions(s)$ $Result(s, a) \rightarrow s_r$
   - s_r *is called a successor of* s
   - $\{s_i\} \cup Successors(s_i)^*$ = *state space*
5. *Performance Measure: Path cost*
   - Must be additive
   - e.g. sum of distances, number of actions executed, …
   - $c(x,a,y)$ is the step cost, assumed ≥ 0
     - (where action a goes from state x to state y)

Formulate Goal

6. *Goal test:* ***Goal(s)***
   - Can be implicit, e.g. ***checkmate(x)***
   - ***s*** is a *goal state* if ***Goal(s)*** is *true*

Find optimal Solution

- **A *solution* is a sequence of *actions* from the *initial state* to a *goal state.***
- ***Optimal Solution:* A solution is *optimal* if no solution has a lower *path cost*.**

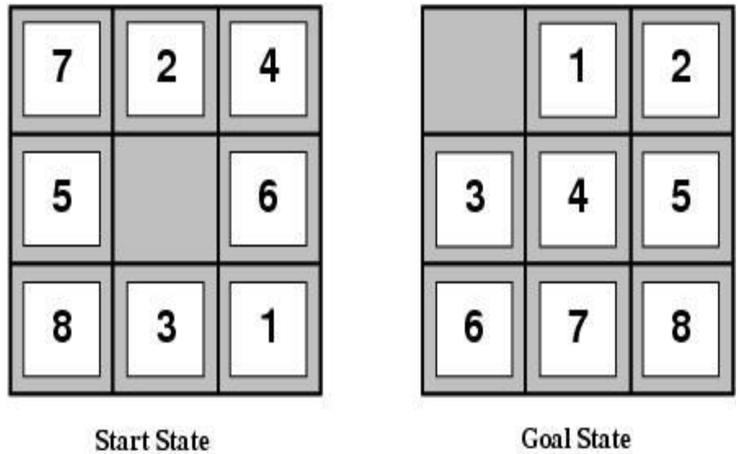
Art: Formulating a Search Problem

Decide:

- **Which properties matter & how to represent**
  - *Initial State, Goal State, Possible Intermediate States*
- **Which actions are possible & how to represent**
  - *Operator Set: Actions and Transition Model*
- **Which action is next**
  - *Path Cost Function*

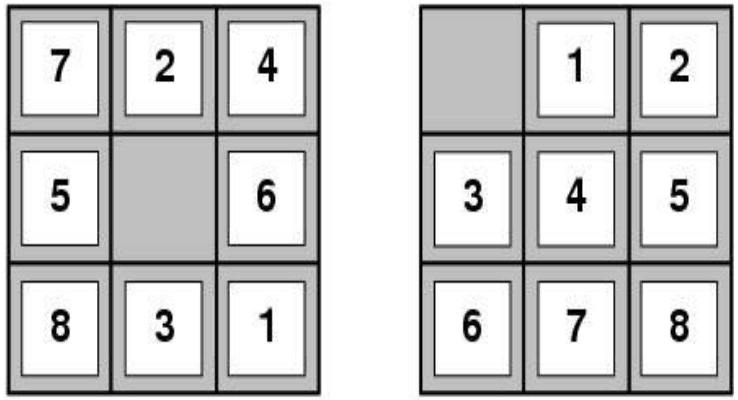
Formulation greatly affects combinatorics of search space and therefore speed of search

Example: 8-puzzle



- **States??**
- **Initial state??**
- **Actions??**
- **Transition Model??**
- **Goal test??**
- **Path cost??**

Example: 8-puzzle



Start State Goal State

- **States??** **List of 9 locations- e.g., [7,2,4,5,-,6,8,3,1]**
- **Initial state??** **[7,2,4,5,-,6,8,3,1]**
- **Actions??** ***{Left, Right, Up, Down}***
- **Transition Model??** **...**
- **Goal test??** **Check if goal configuration is reached**
- **Path cost??** **Number of actions to reach goal**

Hard subtask: Selecting a state space

- **Real world is absurdly complex**

  State space must be *abstracted* for problem solving

- **(abstract) *State* = set (equivalence class) of real world states**

- **(abstract) *Action* = equivalence class of combinations of real world actions**
  - e.g. *Arad* $\rightarrow$ *Zerind* represents a complex set of possible routes, detours, rest stops, etc
  - The abstraction is valid if the path between two states is reflected in the real world

- **Each abstract action should be "easier" than the real problem**

Outline for today's lecture

- **Intelligent Agents**
- **Task Environments**
- **Formulating Search Problems**
- ***Search Fundamentals (AIMA 3.3)***

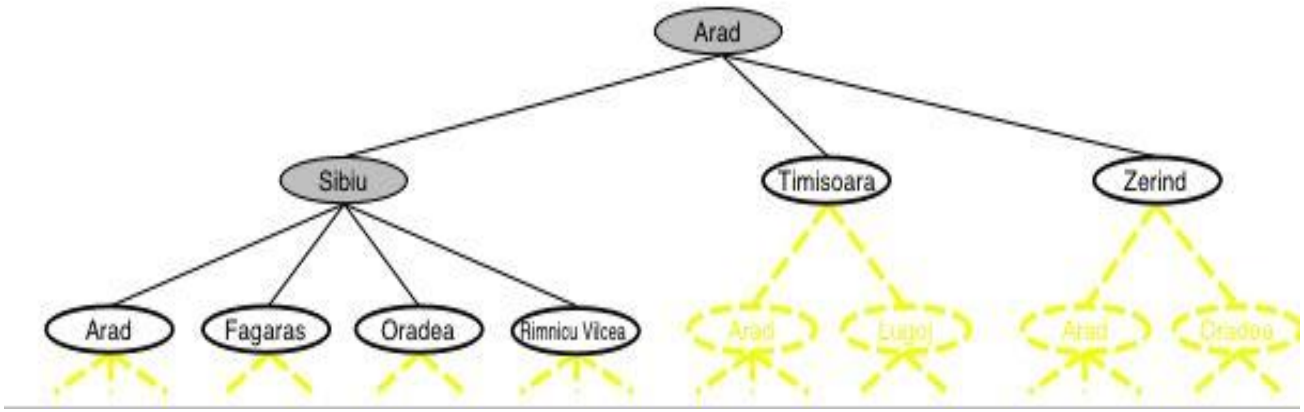
Useful Concepts

- ***State space***: **the set of all states reachable from the initial state by *any* sequence of actions**
  - *When several operators can apply to each state, this gets large very quickly*
  - *Might be a proper subset of the set of configurations*
- ***Path***: **a sequence of actions leading from one state s_j to another state s_k**
- ***Frontier:*** **those states that are available for *expanding* (for applying legal actions to)**
- ***Solution***: **a path from the initial state s_i to a state s_f that satisfies the goal test**

Basic search algorithms: *Tree Search*

- **Generalized algorithm to solve search problems (Review)**
  - *Enumerate in some order all possible paths from the initial state*
  - Here: search through *explicit tree generation*
    - —ROOT= initial state.
    - —Nodes in search tree generated through *transition model*
    - —Tree search treats different paths to the same node as distinct

Review: Generalized tree search

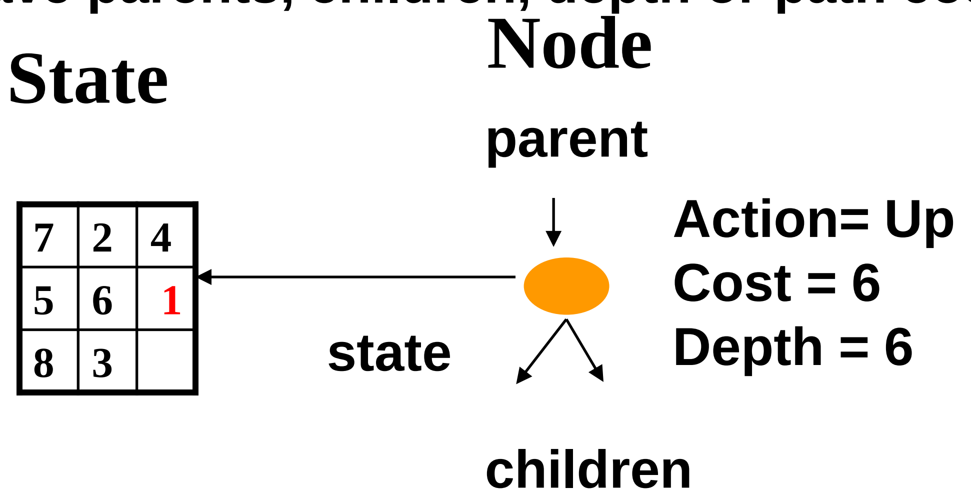


function **TREE-SEARCH(*problem, strategy*)** return **a solution or failure**
Initialize frontier to the *initial state* of the *problem*
do
if **the frontier is empty** then return ***failure***
choose leaf node for expansion according to strategy & remove from frontier
if **node contains goal state** then return ***solution***
else **expand the node and add resulting nodes to the frontier**

Determines search *process!!*

8-Puzzle: States and Nodes

- **A *state* is a (representation of a) *physical configuration***
- **A *node* is a data structure constituting *part of a search tree***
  - Also includes *parent, children, depth*, *path cost g(x)*
  - Here *node= <state, parent-node, children, action, path-cost, depth>*
- **States do not have parents, children, depth or path cost!**

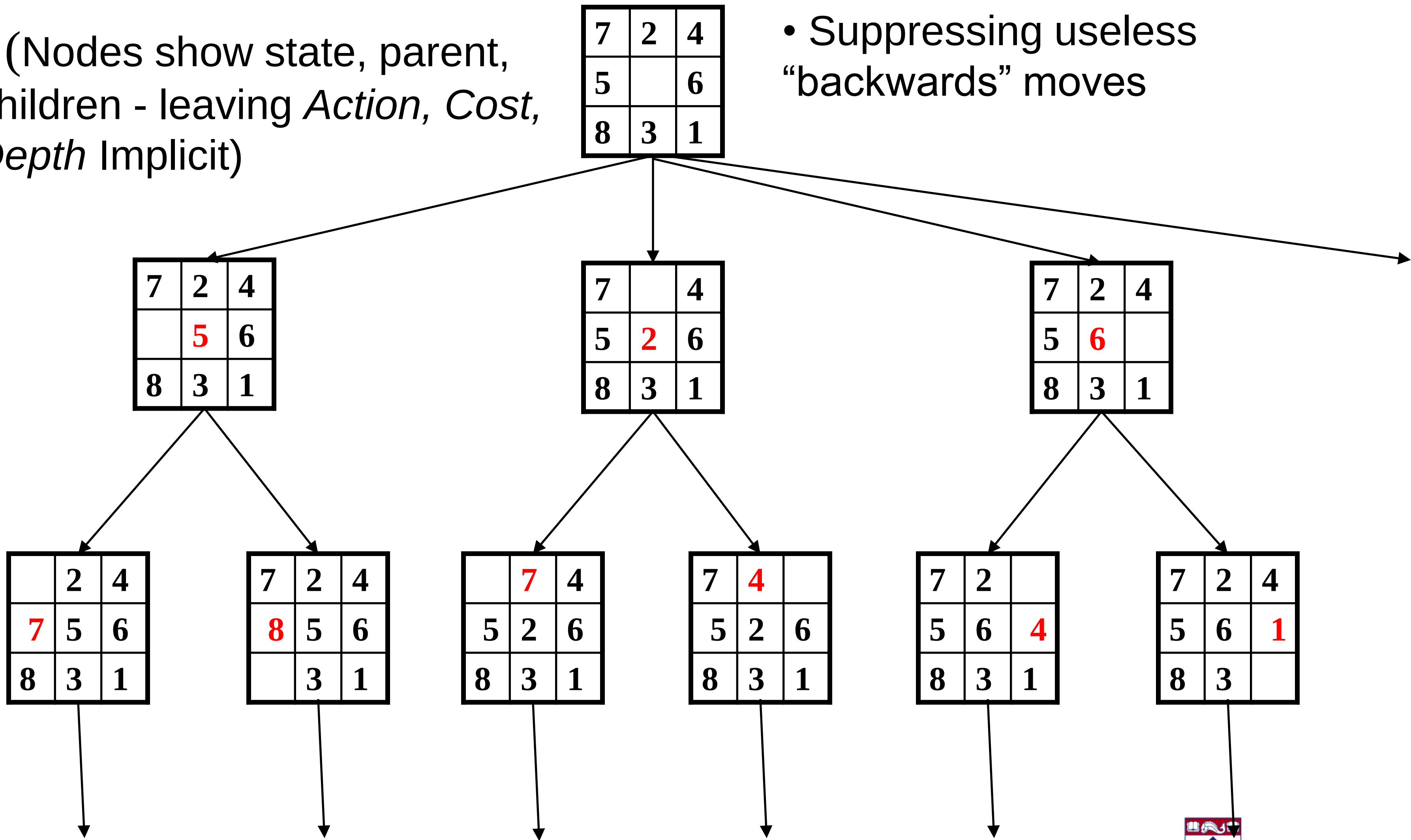


- **The EXPAND function**
  - uses the Actions and Transition Model to create the corresponding states
    - —creates new nodes,
    - —fills in the various fields

8-Puzzle *Search Tree*

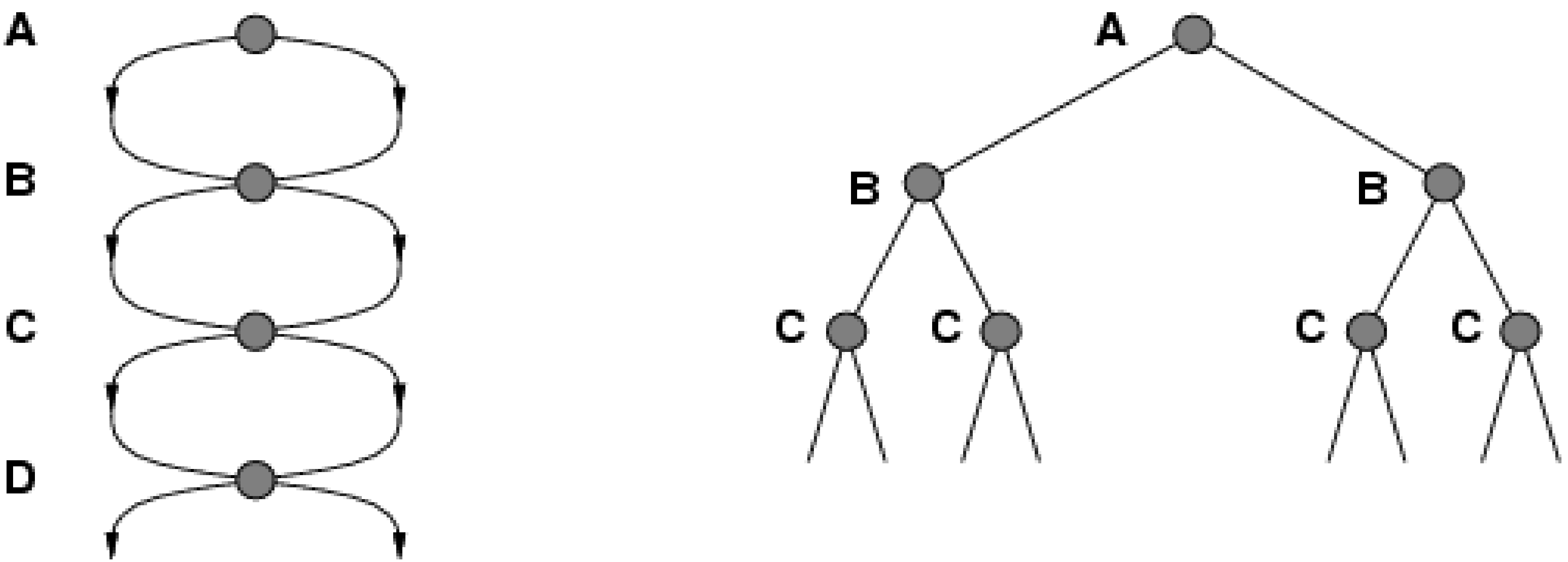
- (Nodes show state, parent, children - leaving *Action, Cost, Depth* Implicit)

- Suppressing useless "backwards" moves

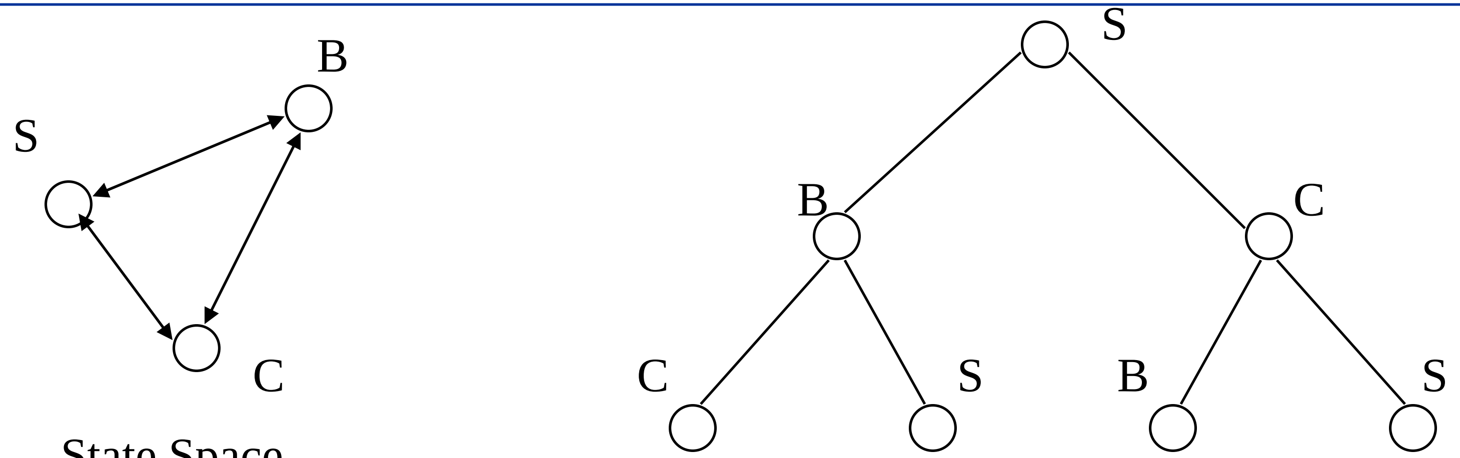


Problem: Repeated states

- **Failure to detect *repeated states* can turn a linear problem into an *exponential* one!**



Solution: Graph Search!



State Space

Search Tree

- **Graph search** ← *Optimal but memory inefficient*
  - Simple Mod from tree search*: Check to see if a node has been visited before adding to search queue*
    - must keep track of all possible states (can use a lot of memory)
    - e.g., 8-puzzle problem, we have 9!/2 ≈182K states

Graph Search vs Tree Search

function TREE-SEARCH(*problem*) **returns** a solution, or failure
  initialize the frontier using the initial state of *problem*
  loop do
    if the frontier is empty **then return** failure
    choose a leaf node and remove it from the frontier
    if the node contains a goal state **then return** the corresponding solution
    expand the chosen node, adding the resulting nodes to the frontier

---

function GRAPH-SEARCH(*problem*) **returns** a solution, or failure
  initialize the frontier using the initial state of *problem*
  initialize the explored set to be empty
  loop do
    if the frontier is empty **then return** failure
    choose a leaf node and remove it from the frontier
    if the node contains a goal state **then return** the corresponding solution
    add the node to the explored set
    expand the chosen node, adding the resulting nodes to the frontier
      only if not in the frontier or explored set

Figure 3.7 An informal description of the general tree-search and graph-search algorithms. The parts of GRAPH-SEARCH marked in bold italic are the additions needed to handle repeated states.