Foundations of Artificial Intelligence

CS472 Lecture #2

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Today's Lecture

Problem Solving as Search

Readings: R&N, Chapter 3.

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Human Problem Solving

Search is a central topic in AI

— Originated with Newell and Simon's work on problem solving. Famous book: "Human Problem Solving" (1972)

— Automated reasoning is a natural search task

— More recently: Given that almost all AI formalisms (planning, learning, etc.) are NP-Complete or worse, some from of search is generally **unavoidable (no "smarter" alg. available)**.

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Defining a Search Problem

State space – described by **an initial state** and the set of possible actions available (**operators**). A **path** is any sequence of actions that lead from one state to another.

Goal test – applicable to a single state to determine if it is the goal state.

Path cost – relevant if more than one path leads to the goal, and we want the shortest path.

Note: very general formulation. Can be somewhat unnatural.

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Two Examples

Cryptarithmetic

(Newell and Simon 1972)

The 8-puzzle

Example I : Cryptarithmetic

```
    SEND
+   MORE
--------
   MONEY
```

Find substitution of digits for letters such
that the resulting sum is arithmetically correct.
Each letter must stand for a different digit.

Cryptarithmetic, cont.

States: a (partial) assignment of digits to letters.

Operators: the act of assigning digits to letters.

Goal test: all letters have been assigned digits and sum is correct.

Path cost: zero. All solutions are equally valid.

State Space Search

Input:

- Start state
- Goal state or goal test
- Operators

Output: legal sequence of nodes from initial node to goal node

Search space is generally **not** stored in its entirety.

example search space cryptarithmetic
DFS (depth-first search)

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Cryptarithmetic

Is this (DFS) how humans tackle the problem?

And, if not, what do humans do?

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Human problem solving appears much more **sophisticated!**

For example, we derive new constraints on the fly.

In a sense, we try to solve problems with **little** or **no** search!

In example, we can immediately derive that $M = 1$.
It then follows that $S = 8$ or $S = 9$. Etc. (derive more!)

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Capturing such human problem solving strategies is surprisingly difficult. *For example, how do we know to first consider assigning M?*

Constraint programming techniques do provide some steps towards this kind of problem solving (next lecture).

Fortunately, computers are **very good at fast search!**
Search speed can **compensate** for lack of higher-level insights into the problem structure.

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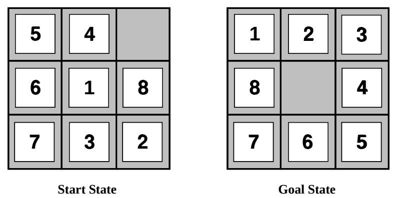
Example II : The 8-Puzzle

States: Specifies the location of each of the eight tiles in one of the nine squares

Operators: blank moves left, right, up, down

Goal test: state matches the goal configuration

Path cost: each step costs 1, so path cost = length of path



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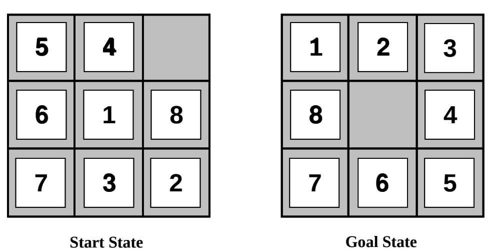
Solving the 8-Puzzle



What would the search tree look like after the start state was expanded?

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Solving a Search Problem

Search problems are solved by searching the state space.

Search process builds up a *search tree* over the search space.

Root = the initial state

Leaves = states that do not have successors in the tree (none exist or node has not been expanded yet).

Search strategy = algorithm for deciding which leaf node to expand next.

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Generic Search Algorithm

```
L = make-queue/stack(initial-state)
loop
        node = remove-front(L)
        if goal-test(node) = true return( node )
        S = successors(node, operators)
        insert(S,L)
until L is empty
return failure
```

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Search procedure defines a search tree

root node — initial state

children of a node — successors of the node

fringe of tree — L: nodes not yet expanded

stack: Depth-First Search (DFS).

queue: Breadth-First Search (DFS).

Aside: Actual implementation may not use stack/queue.