Search	1 handout: slides
Basic Algorithms	
A Clever Algorithm	
EOLQs	

Search

Basic Algorithms

A Clever Algorithm

EOLQs

Search

- Contents
- Cognitive Science
- Problem Solving
- $\blacksquare Representation$

Basic Algorithms

A Clever Algorithm

EOLQs

Search

Wheeler Ruml (UNH)

Contents

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- Cognitive Science
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EOLQs

This particular pattern of molecules known as a 'human being' has evolved an amazing depth of consciousness: an ability to internally model the reality beyond the senses, to imagine futures that have never happened, to use language, to use rationality to build and test theories about our universe, to become self-aware. —Jeff Lieberman (artist, roboticist)

Cognitive Science

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EOLQs

The ability to think is perhpas the most distinctive of human capacities. Typically, thinking involves mentally representing some aspects of the world (including aspects of ourselves) and manipulating these representations or beliefs so as to yield new beliefs, where the latter may aid in accomplishing a goal. —Edward E. Smith (Psychology, U Michigan)

The ability to solve problems is one of the most important manifestations of human thinking. ... We might therefore suspect that problem solving depends on general cognitive abilities that can potentially be applied to an essentially unlimited range of domains.

-Keith Holyoak (Psychology, UCLA)

Formalizing Problem Solving

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Basic Algorithms

A Clever Algorithm

EOLQs

State: hypothetical world stateOperators: actions that modify worldGoal: desired state or test



(Herbert Simon and Allen Newell, "Computer simulation of human thinking and problem solving", 1961)

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Representation

Search

Contents

■ Cognitive Science

■ Problem Solving

Representation

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EOLQs

VW search space VW state space MC representation

Search

Basic Algorithms

- Alg 1
- Alg 2
- Uniform-cost
- Graphs
- Comparison
- Time vs space
- Both?
- Break
- A Clever Algorithm
- EOLQs

Basic Algorithms

-First Search

S	ea	ər	c	h
-	~		C	

Basic Algorithms

- Alg 1■ Alg 2
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EOLQs

open \leftarrow an ordered list containing just the initial state. Loop

```
If open is empty,
then return failure.
```

```
Node \leftarrow Pop(open).
```

```
If Node is a goal,
```

```
then return Node (or path to it).
```

```
else
```

```
Children \leftarrow Expand (Node).
Add Children to front of open.
```

Evaluating DFS

Search	Assu
Basic Algorithms	
☐ Alg 1	Cor
Alg 2	
Uniform-cost	
■ Graphs	
Comparison	_
■ Time vs space	Ac
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Break	
A Clever Algorithm	
EOLQs	

Ime branching factor b and solution at depth d.

mpleteness: Time: Space: dmissibility:

Search

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- Alg 1
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EOLQs

open \leftarrow an ordered list containing just the initial state. Loop

```
If open is empty,
then return failure.
Node ← Pop(open).
If Node is a goal,
then return Node (or path to it).
```

else

Children \leftarrow **Expand** (Node). Add Children to end of open.

 \leftarrow

Evaluating BrFS

Search	Ass
Basic Algorithms	
■ Alg 1	C
I Alg 2	-
Uniform-cost	
■ Graphs	
Comparison	
■ Time vs space	A
■ Both?	
Break	
A Clever Algorithm	
EOLQs	

sume branching factor b and solution at depth d.

ompleteness: Time: Space: Admissibility:

Search	
Search	

Basic Algorithms

- Alg 1Alg 2
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EOLQs

open \leftarrow an ordered list containing just the initial state. Loop

```
If open is empty,
```

then return failure.

```
Node \leftarrow Pop(open).
```

```
If Node is a goal,
```

then return *Node* (or path to it).

else

```
Children \leftarrow Expand (Node).
```

Merge *Children* into open, keeping sorted by path cost.

Dealing with Graphs

Search

Basic Algorithms

- Alg 1Alg 2
- Uniform-cost

Graphs

- Comparison
- Time vs space
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- A Clever Algorithm

EOLQs

- 1. Check for cycles with ancestors
- 2. Maintain closed list (hash table) to detect duplicates

Comparison

Search	Algorithm	Time	Space	Complete	Admissible
Basic Algorithms	Depth-first	b^m	bm	If $m \ge d$	No
■ Alg 1 ■ Alg 2	Breadth-first	b^d	b^d	Yes	If ops cost 1
 ■ Uniform-cost ■ Graphs 	Uniform-cost	b^d	b^d	Yes	Yes
Comparison					
Both?Break	branching fact	orb thm			
A Clever Algorithm EOLQs	solution dept	th d			

Time and Space for BrFS/UCS

Search	Assume $b = 1$	10; 100,0	00 nodes/se	ec; 100 byt	es/node.
Basic Algorithms	Sol. depth	Nodes	Time	Space	
■ Alg 1	1	11	.11 msec	1.1 Kb	
 Alg 2 Uniform-cost 	2	111	1.1 msec	11 Kb	
■ Graphs ■ Comparison	4	11,111	.11 sec	1 Mb	
☐ Time vs space	6	10^{6}	11 sec	111 Mb	
■ Both?■ Break	8	10^{8}	18 min	11 Gb	
A Clever Algorithm	10	10^{10}	31 hours	1 Tb	
EOLQs	12	10^{12}	128 days	111 Tb	
	14	10^{14}	35 yrs	11 Pb	

Search Conundrum

Search

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EOLQs

Breadth-first uses b^d space but complete and admissible Depth-first complete only if limit > d, not admissible but bd space

How can we get the best of both?

Break

Search

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- textbook
- piazza
- asst 1
- sources
- recitation
- office hours

Basic Algorithms

- A Clever Algorithm
- IDS
- Evaluating IDS
- \blacksquare IDS time

EOLQs

A Clever Algorithm

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Iterative Deepening Search

Search

Basic Algorithms

A Clever Algorithm

■ IDS

■ Evaluating IDS

■ IDS time

EOLQs

for d = 1 to ∞ do depth-first search to level dif it succeeds then return solution

Could this possibly be efficient?

Evaluating IDS

Search	Assume branchin	g factor b and	solution a	at depth d .
Basic Algorithms				
A Clever Algorithm	Completeness:			
■ IDS	Time			
Evaluating IDS				
■ IDS time	Space:			
EOLQs	Admissibility [.]			

Space: Admissibility:

Search	b=2					
Basic Algorithms	d	at d	in prev.	total	IDS	% of opt.
A Clever Algorithm	0	1	0	1	1	100.0
 IDS Evaluating IDS 	1	2	1	3	4	133.3
□ IDS time	2	4	3	7	11	157.1
EOLQs	34	16	15	31	57	183.9
	b = 10					
	d	at d	in prev.	total	IDS	% of opt.
	0	1	0	1	1	100.0
	1	10	1	11	12	109.1
	2	100	11	111	123	110.8
	34	10000	1111	11,111	12,345	111.1

Nodes Generated by IDS

Search

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■ IDS

■ Evaluating IDS

■ IDS time

EOLQs

$$b^{d} + 2b^{d-1} + 3b^{d-2} + \dots + (d-1)b^{2} + db$$

$$\approx b^d (\frac{b}{b-1})^2$$

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EOLQs

EOLQs

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EOLQs

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EOLQs

Please write down the most pressing question you have about the course material covered so far and put it in the box on your way out. *Thanks!*