EOLQs
Are We Done?
Beyond A*
Suboptimal Search
Anytime Search
EOLQs

■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

Are We Done?



■ Are We Done?

Beyond A* ■ GBFS

■ 8-puzzle

Evaluating Greedy

Beam Search

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

Beyond A*

■ EOLQs ■ Are We Done?	$Q \leftarrow$ an ordered list containing just the initial state.
Beyond A*	Loop
GBFS	If Q is empty,
■ 8-puzzle	then return failure.
 Evaluating Greedy Beam Search 	Node $\leftarrow \operatorname{Pop}(Q)$.
Suboptimal Search	If Node is a goal
Anytime Search	then return Node (or noth to it)
Real-time Search	
EOLQs	
	$Children \leftarrow Expand (Node).$
	Merge <i>Children</i> into Q , keeping sorted by heuristic . \leftarrow

GBFS on the 8-puzzle

■ EOLQs ■ Are We Done?	h(n) = num	ber	of ti	les	out of	place	e. (The	bla	nk is	s not a	a tile.))
Beyond A* GBFS 8-puzzle Evaluating Greedy Beam Search	Start state:	2 1 7	8 6 ⊔	3 4 5		Goal	state:	1 8 7	2 ⊔ 6	3 4 5		
Suboptimal Search Anytime Search Real-time Search EOLQs	Please draw	the	tree	res	ulting	from	the firs	t tw	o no	ode ex	pansio	ons

FOI Qs	
LOLQS	

■ Are We Done?

Beyond A* ■ GBFS

■ 8-puzzle

Evaluating Greedy

Beam Search

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

Assume branching factor b and solution at depth d.

Completeness: Time: Space: Admissibility:

Beam Search

	EOI	_Qs
_		

■ Are We Done?

Beyond A* ■ GBFS

■ 8-puzzle

■ Evaluating Greedy

Beam Search

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

Truncate queue to hold the most promising k nodes. k is the *beam width*. Works best with breadth-first search!

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■ Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

∎ wA*

■ wA* Behavior

■ Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs

Suboptimal Search

Problem Settings

 EOLQs Are We Done? Beyond A* 	optimal: minimize solution cost suffer all with $f(n) = g(n) + h(n) < f^*$
Suboptimal Search Problem Settings wA* 	greedy: minimize solving time
 wA* Behavior Distance-to-go RR-d 	bounded suboptimal: minimize time subject to relative cost bound (factor of optimal)
Anytime Search Real-time Search EOLQs	bounded cost: minimize time subject to absolute cost bound
	contract: minimize cost subject to absolute time bound
	anytime: iteratively converge to optimal
	utility: maximize given function of cost and time



■ Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

∎ wA*

■ wA* Behavior

Distance-to-go

 $\blacksquare \mathsf{RR}\text{-}d$

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Anytime Search
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Real-time Search

EOLQs

$$f'(n) = g(n) + w \cdot h(n)$$

- nodes with high h(n) look even worse
- no infinite rabbit holes
- suboptimality bounded: within a factor of w of optimal!

wA* Behavior





optimal: uniform-cost search

wA* Behavior



Beyond A*

Suboptimal Search

 $\blacksquare Problem Settings$

∎ wA*

■ wA* Behavior

■ Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs



optimal: A*

wA* Behavior



■ Are We Done?

Beyond A*

Suboptimal Search

 $\blacksquare Problem Settings$

∎ wA*

■ wA* Behavior

■ Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs



bounded suboptimal: Weighted A*

EOLQsAre We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

■ Distance-to-go

 \blacksquare RR-d

Anytime Search

Real-time Search

EOLQs

how to minimize solving time?

EOLQs

■ Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

■ Distance-to-go

 \blacksquare RR-d

Anytime Search

Real-time Search

EOLQs

how to minimize solving time? how to minimize number of expansions?

EULUS	

■ Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

■ Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs

how to minimize solving time? how to minimize number of expansions? take the shortest path to a goal

■ EOLQs

Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs

how to minimize solving time? how to minimize number of expansions? take the shortest path to a goal for domains with costs, this is not h(n)

new information source: distance-to-go= d(n)



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■ EOLQs

Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

Distance-to-go

 $\blacksquare \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs

how to minimize solving time? how to minimize number of expansions? take the shortest path to a goal for domains with costs, this is not h(n)

new information source: distance-to-go= d(n)



Speedy: best-first search on d

Round Robin d

■ EOLQs Are We Done? Beyond A* Suboptimal Search ■ Problem Settings ■ wA* ■ wA* Behavior ■ Distance-to-go \square RR-dAnytime Search Real-time Search EOLQs

bounded-suboptimal using h, \widehat{h} , d



optimal: uniform-cost

Round Robin d



■ Are We Done?

Beyond A*

Suboptimal Search

Problem Settings

■ wA*

■ wA* Behavior

■ Distance-to-go

 $\square \mathsf{RR-}d$

Anytime Search

Real-time Search

EOLQs

bounded-suboptimal using h, \widehat{h} , d



optimal: A*

Round Robin \boldsymbol{d}



bounded-suboptimal using h, \widehat{h} , d



bounded suboptimal: Weighted A*

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Round Robin \boldsymbol{d}



bounded-suboptimal using h, \widehat{h} , d



bounded suboptimal: Optimistic Search (ICAPS, 2008)

Round Robin d



bounded-suboptimal using h, \widehat{h} , d



bounded suboptimal: Explicit Estimation Search (IJCAI, 2011)

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■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

■ Anytime A*

Break

Real-time Search

EOLQs

Anytime Search

Wheeler Ruml (UNH)

Anytime A*

EOLQs

Beyond A*

Break

EOLQs

■ Are We Done?

Suboptimal Search

Anytime Search
Anytime A*

Real-time Search

- 1. run weighted A*
- 2. keep going after finding a goal
- 3. keep best goal found (can test at generation)
- 4. prune anything with f(n) > incumbent

Anytime Restarting A* (ARA*): lower weight after finding each solution Anytime EES

Break

EOLQs

Are We Done?

Beyond A*

Suboptimal Search

Anytime Search ■ Anytime A*

Break

Real-time Search

EOLQs

asst2 (asst8), asst 3 scores and grades

■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

Real-time Search

■ RTA*

- LSS-LRTA*
- Search Algorithms

Other Algorithms

EOLQs

Real-time Search

Wheeler Ruml (UNH)

RTA*

EOLQs

■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

Real-time Search

RTA*

LSS-LRTA*

Search AlgorithmsOther Algorithms

EOLQs

keep hash table of \boldsymbol{h} values for visited states

- 1. for each neighbor of current state \boldsymbol{s}
- 2. either find h in table or do some lookahead
- 3. add edge cost to get f
- 4. update h(s) to second-best f value
- 5. move to best neighbor

LSS-LRTA*

EOLQs

- Are We Done?
- Beyond A*
- Suboptimal Search

Anytime Search

Real-time Search

■ RTA*

- LSS-LRTA*
- Search Algorithms
- Other Algorithms

EOLQs

- 1. single A* lookahead (LSS)
- 2. update all h values in LSS
- 3. move to frontier

Search Algorithms

EOLQs	Uninf
Are We Done?	Admi
Beyond A*	Limit
Suboptimal Search	Satisf
Anytime Search	Roun
Real-time Search	Doun
■ RTA*	Real-1
■ LSS-LRTA*	
Search Algorithms	
Other Algorithms	
EOLQs	

Jninformed: DFS, UCS Admissible: A* Limited memory: iterative deepening (IDDFS, IDA*) Satisficing: GBFS, Speedy, Beam Bounded suboptimal: wA*, RR-*d* Real-time: RTA*, LSS-LRTA*

Other Shortest-path Algorithms

EOLQs

- Are We Done?
- Beyond A*
- Suboptimal Search
- Anytime Search
- Real-time Search
- RTA*
- LSS-LRTA*
- Search Algorithms
- Other Algorithms
- **EOLQs**

- SMA*, IE
- **RBFS**
- Bugsy
- **Rectangle Search**
- any-angle pathfinding, Euclidean pathfinding
- multiobjective search
 - multi-level planning: TAMP, MAPF
- Course projects!

■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

EOLQs

EOLQs

Wheeler Ruml (UNH)

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■ Are We Done?

Beyond A*

Suboptimal Search

Anytime Search

Real-time Search

EOLQs

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!*