6.034
Search

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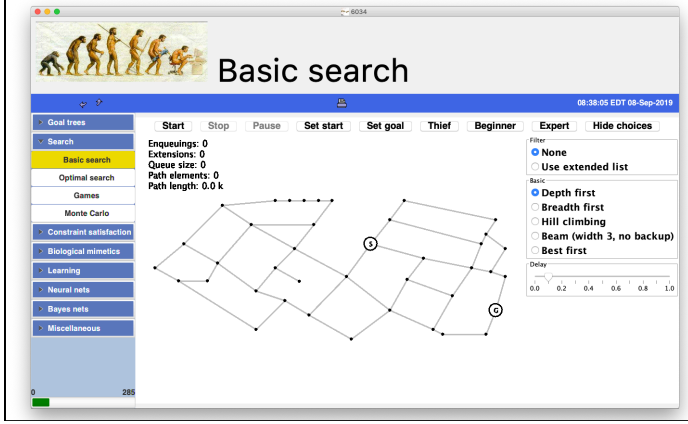
Remember

- AI is …
- Algorithms/methods enabled by
  - Constraints exposed by
    - Representations that support
      - Models of
        - Thinking, perception and action

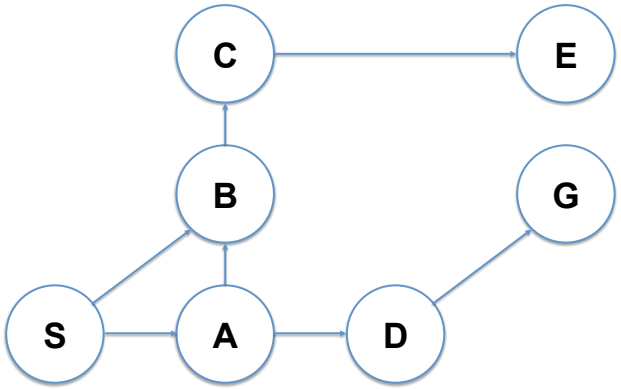
Search

- A class of algorithms that allow exploration of *abstract* plans (= sequences of actions)

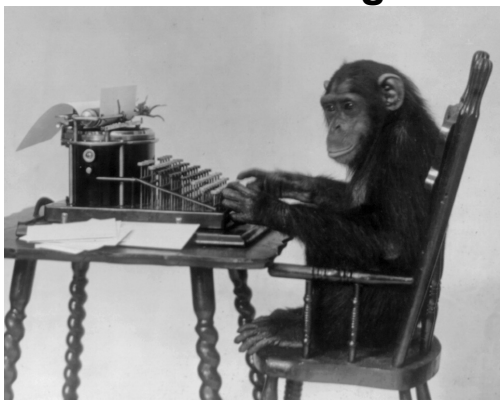
Map Search: Cambridge



Cambridge, Simplified



British Museum Algorithm



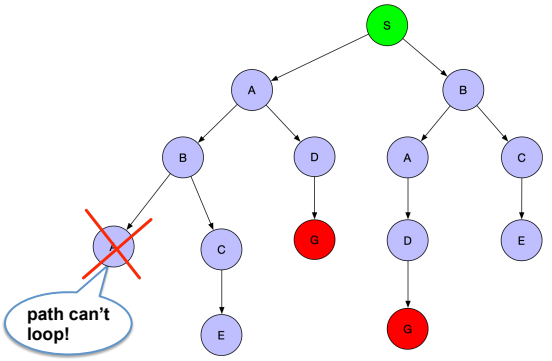
"placing monkeys in front of typewriters in order to reproduce all the books in the British Museum"

BM (Random Search)

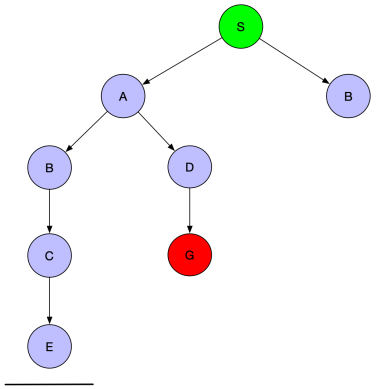
```
['SASADASBSBCBCBCECECECECECECBCEC…',
 'SBADG',
 'ASBSBABSBABSBCECECECBADG',
 'SABCECECBSADG',
 'SBADASADG',
 'SADASBADG',
 'SASADADG',
 'SASBSASBSBCECBSADASBCBCECBCBABA…',
 'SADG',
 'SASBABASBSASBCECECBCECECBADASAS…',
 'SABSBCBADADASASADG',
 'SASBADG',
 'SADG',
 'SADG',
 'SADADADASBABASABSABASBSADG',
 'SABSABSBCBCECBCECBASBCBADG',
 'SABSADADG',
 'SBADASABADADG',
 'SBCBABCBSBSBABADG',
 'SBASADG',
 'SASABCECECECECBCECBCECECECECBSA…',
'SADASBSADADG',
'SBSBABSBSASADASBSBCBCBSBSBSBSBC…',
```

```
'SADADASBSBABCBSADG',
'SADABADG',
'SASBSASASBASBSBASBSBADG',
'SADABABADG',
'SADG',
'SBSBASASBASBCBADG',
'SBCECECECECECECECECBCECBCECECEC…',
'SBCBSABCBCECBCBSBSASBSBCBSABCBA…',
'SABADASADASASBSADG',
'SBSADG',
'SABASBSBABSBCBABCECBSABCECBSBSA…',
'SBABSBSBSASASBCBABCBSBSASBADG',
'SBADASASABCECECBCBASBSADG',
'SBSBSBSBSASBSBCBCBADG',
'SADG',
'SBASADADG',
'SBSADADASASBSBCBSASADASASBASADA…',
…]
```

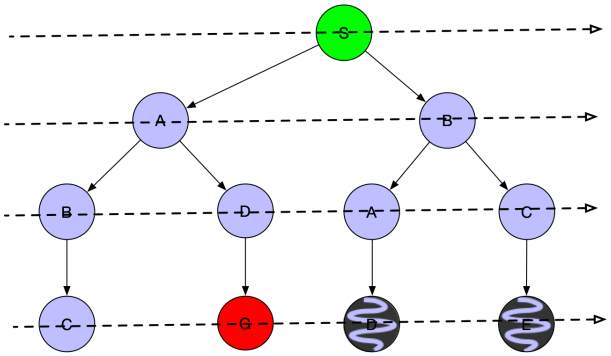
“British Museum” Search



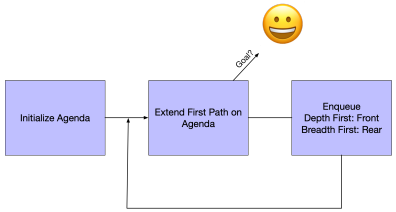
Depth First Search



Breadth First Search



Generic Algorithm

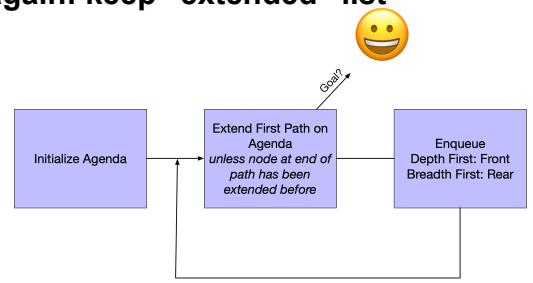


Agenda for depth first search:

(S)
(S A) (S B)
(S A B) (S A D) (S B)
(S A B C) (S A D) (S B)
(S A B C E) (S A D) (S B)
(S A D) (S B)
(S A D G) (S B)

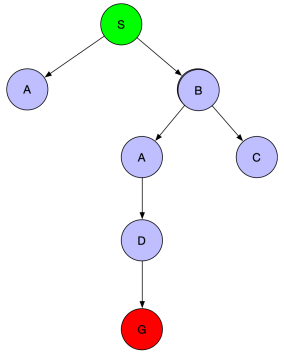
Avoid Duplication

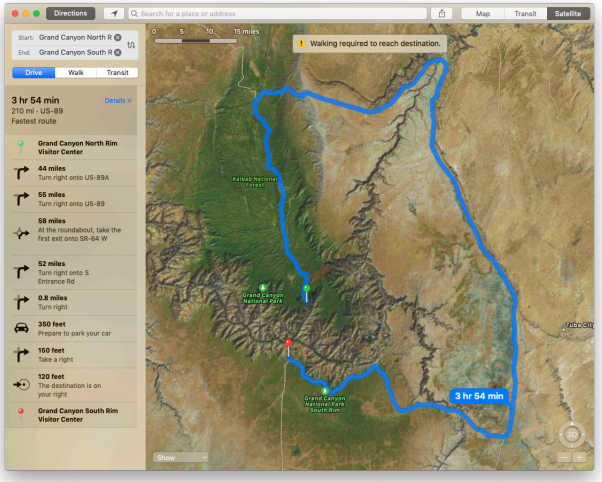
- **Don't expand paths from the same node again: keep "extended" list**



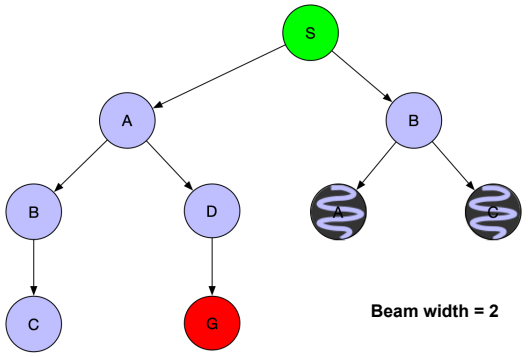
Hill Climbing

- Prefer paths that lead *toward* the goal!
- Need an estimate of distance to goal: "as the bird flies"





Beam Search



Beam width = 2

Variations in the Generic Method

Algorithm	Extend which Q entry?	Add extensions to Q	Possible path guaranteed?
Depth First	first	front	yes
Breadth First	first	back	yes
Hill Climbing w/ backtrack	first	front, sorted by H*	yes
Beam	best by H*	anywhere	no
Best First	best by H*	anywhere	yes

H* is estimate of distance to goal

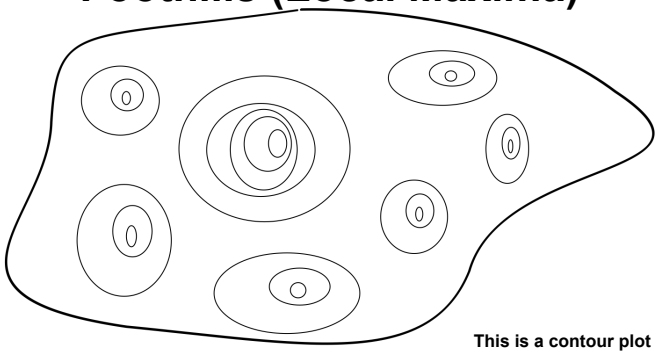
Search of Maps

Algorithm	Backtracking	Extended list	Informed (heuristic info)
"British Museum"	✘	✘	✘
Depth First	✓	✓	✘
Breadth First	✘	✓	✘
Hill Climbing	✓	✓	✓
Beam	✘	✓	✓

Hill Climbing in *Continuous Spaces* e.g., walk to top of mountain

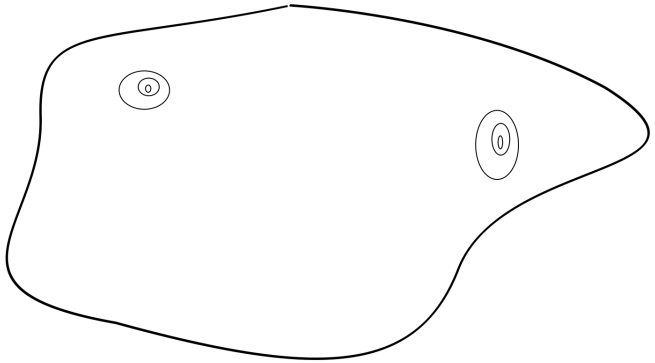
- Infinite number of possible extension
- Often have only *local* estimate of best direction rather than distance to goal
- Potential problems:
  - Local maxima
  - Plateau
  - Ridge

Foothills (Local Maxima)

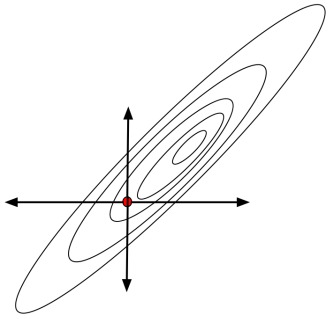


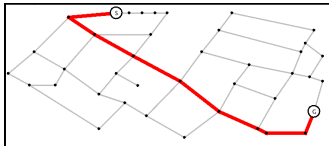
This is a contour plot

Plateau



Ridge





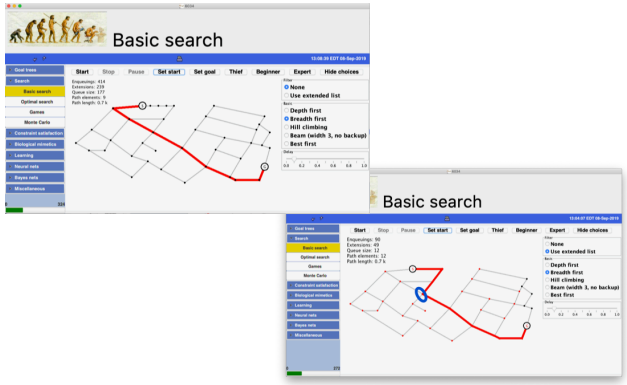
How Much Work?

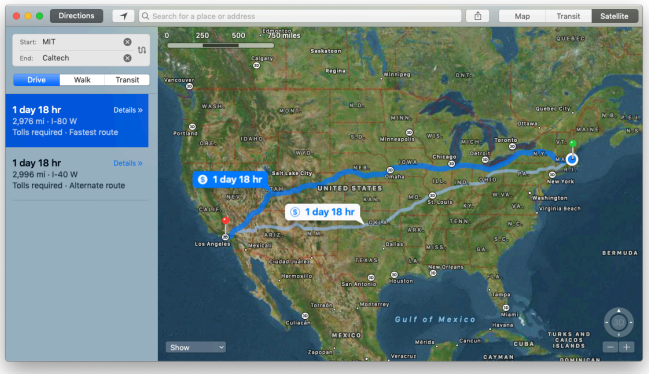
Algorithm	Enqueuings	Extensions	Max queue size	# nodes in path
Depth First	48	32	18	29
Breadth First	414 *90*	239 *49*	177 *12*	9 *12*
Hill Climbing	27	14	15	14
Beam	46 *34*	24	3	9
Best First	27	14	14	14

italic results use extended list as optimization
no difference if not listed in table

why? artifact of demo implementation

Different Results from Different Notions of Distance





What Problems Can You Formulate as Search?

- Integration
- Class schedules
- Traveling Salesman
- VLSI layout
- Drug synthesis
- Sequencing manufacturing steps
- Diagnosis of co-occurring diseases
- …