UE Artificial Intelligence

344.021, 344.022, 344.023
WS 2015

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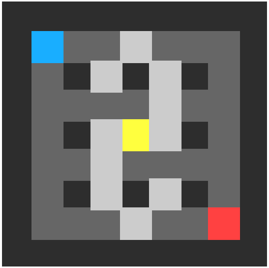
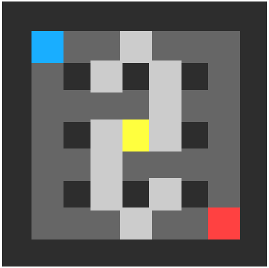
October 12, 2015

A short example - “What if ... ?”



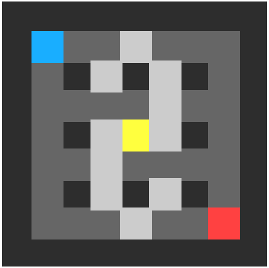
- assuming we wanted to search the state space of the 1 vs. 1 game depicted on the left by exhaustive search - to find the best moves simply by enumerating all possible game states
- to do this, we first have to determine **how many bits** we need to specify **one state**
- 41 paths, 10 clouds, 1 fountain, 2 unicorns, 3 seeds each, move limit is 50

Unicorn position



- if we simply index the walkable tiles (paths), the position of the unicorns can be represented by such an index value
- we need to be able to distinguish 41 positions for each unicorn
- for 2 unicorns, that's $\log_2(41^2)$ = **11 bits**
- the adjacency matrix for indices needs to be remembered only once
- if we would have included the non-walkable tiles, we would have needed $\log_2((9^2)^2) = 13$ bits

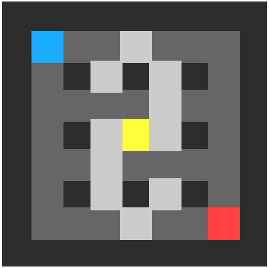
Seed position



- the position of seeds can be represented by an index as well

- a seed has a fuse length of 8
- naively, for 2 unicorns and 3 seeds each, that makes $\log_2(41^6 + 8^6) =$ **33 bits**
- "naively" because we did not take into account the effect that the fuse timing has on seed position - constraining the maximum distance a seed may have from a unicorn

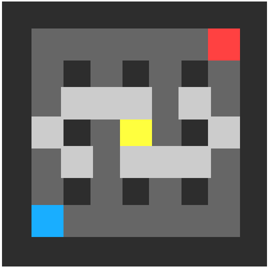
Rainbow positions



- again, the position of rainbows can be represented by an index

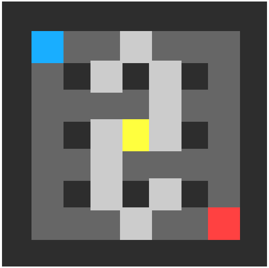
- but in this case, we only need to check which walkable positions are affected
- a seed blossoms into 9 rainbow tiles, so modelling them the same as we did the seeds would be wasteful ($\log_2 41^{2\cdot3\cdot9} = 290$ bits)
- instead, we'll use exactly **41 bits** because we do not care about overlap

Cloud positions



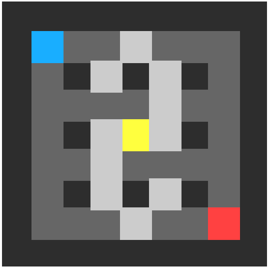
- clouds are a bit different again, insofar as we only need to store whether a walkable tile is blocked
- naively 1 bit for each possible position - 41 bits
- actually, we only need enough bits to model the maximum index - if we turn the board, this saves a few bits
- in this example case, we only need **29 bits** if we start in the upper left corner with indexing

Fountains (1)



- we need be able to store scores for all unicorns on the board, for each fountain
- the maximum score possible is the move limit (minus the length of the path in state space from starting position to the fountain in question)
- the path length is 6 moves for a single unicorn, the unicorns take turns, for a path length in state space of 12, the move limit is 50, which (naively) makes a maximum achievable score of 38

Fountains (2)



- naively, because we do not model the possibilities that the other unicorn stands on the same fountain (no golden stars, for either unicorn)
- we need to keep track of scores for 2 unicorns, and 1 fountain
- $\log_2 38^2$ = **11 bits**

How many bits to describe a state ?

Hairy approximations up ahead ...

Unicorns	11 bits
Seeds	33 bits
Rainbows	41 bits
Clouds	29 bits
Fountains	11 bits
Sum	125 bits

- We have 2^{125} possible boards
- Assuming we can compute a score in 50 instructions on an (overclocked) 5GHz machine

@1GHz, 1 instr., T = 1 [ns]

@5GHz, 1 instr., T = 0.2 [ns]

@5GHz, 50 instr., T = 10 [ns]

- $2^{125} \cdot 10 \cdot 10^{-9}$ [s]
- $60 \cdot 60 \cdot 24 \cdot 356$ [s] per year
- $\approx \mathbf{1.3 \cdot 10^{22}}$ **[years]** to exhaustively search the state space!
- $\frac{2^{125}}{1000^8} \approx \mathbf{42 \cdot 10^{12}}$ **[YB]** to store the search space

Perspective

- "an internet" was roughly $2.4 \cdot 10^{21}$ [bits] in 2007
- our state space is equivalent to $1.6 \cdot 10^{16}$ [internets]
- the information capacity of the observable universe is 2^{305} [bits]
- our state space would then be a $\frac{1}{2^{180}}$ th [universe]
- our state space is smaller than Chess, with about 10^{47} states
- our state space is smaller than Go, with about 10^{171} states

Assignment 0 - Proper Formatting

- the zeroth assignment exists to make sure you know how to properly format the **zip** archive that you have to hand in for each assignment
- make sure you and your partner **both** know how to do it
- once you created the archive, **unpack** it in an empty folder to actually **check** you did it correctly

Assignment 1 - Search in Graphs

- uninformed search (BFS, DLDFS, IDS)
- cost sensitive search (UCS)
- heuristic search (GBFS)
- cost and heuristic search (ASTAR)
- search in **graphs** means you have to keep a datastructure around that tells you which nodes you already expanded
- the **asymptotic runtime complexity** of the **insert** and **lookup** operations on this datastructure are **important**

Search in Graphs

- we want to avoid doing more work than necessary
- especially if we have a “loopy” state space
- there are three basic possibilities

Cycle Avoidance - Tradeoffs

- do not expand **parent** node again (trivial, basically free)
- do not expand a node from the **current path** again (“self-avoiding walk”)
- do not expand **any visited** node again (“closed list”)

Organizational Stuff

- Assignments 0 & 1 will be uploaded this afternoon
- You’ll receive your groupnames this afternoon / evening as well

Questions

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