

COMP250: Artificial Intelligence

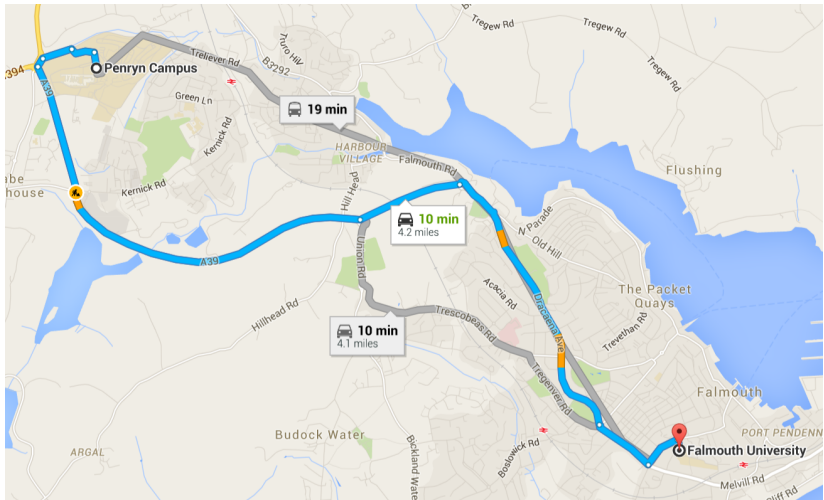
9: Navigation

Pathfinding

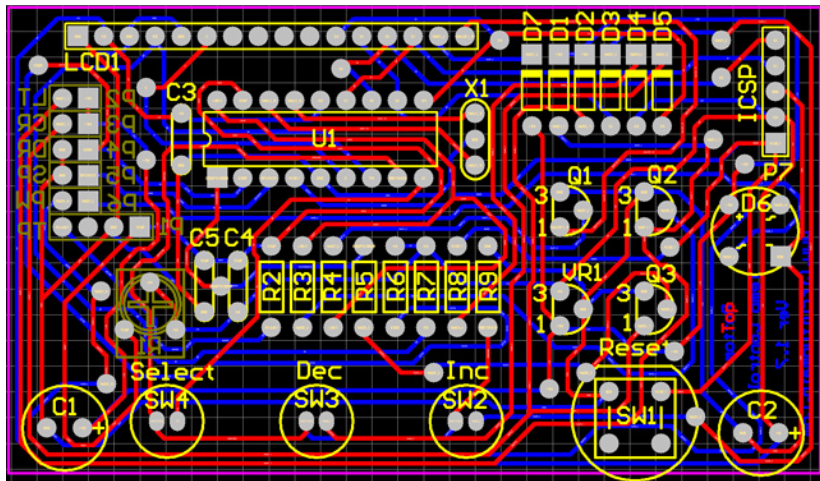
The problem

- ▶ We have a **graph**
 - ▶ **Nodes** (points)
 - ▶ **Edges** (lines between points, each with a **length**)
- ▶ E.g. a road map
 - ▶ Nodes = addresses
 - ▶ Edges = roads
- ▶ E.g. a tile-based 2D game
 - ▶ Nodes = grid squares
 - ▶ Edges = connections between adjacent squares
- ▶ Given two nodes *A* and *B*, find the **shortest path** from *A* to *B*
 - ▶ “Shortest” in terms of edge lengths — could be distance, time, fuel cost, ...

Applications of pathfinding



Applications of pathfinding



Applications of pathfinding

Many applications in game AI

- ▶ Non-player character AI
- ▶ Mouse-based movement (e.g. strategy games)
- ▶ Maze navigation
- ▶ Puzzle solving

Pathfinding example

- ▶ `https://github.com/falmouth-games-academy/comp250-workshop-9`
- ▶ Open it in PyCharm

Graph traversal

- ▶ **Depth-first** or **breadth-first**
- ▶ Recall: can be implemented with a **stack** or a **queue** respectively
- ▶ For graphs (as opposed to trees), need to remember which nodes have been **visited** to avoid getting stuck in a loop
- ▶ Inefficient — generally has to explore the **entire map**
- ▶ Finds a path, but probably not the **shortest**
- ▶ Third type of traversal: **best-first**
 - ▶ “Best” according to some heuristic evaluation
 - ▶ Often implemented with a **priority queue**

Greedy search

- ▶ Always try to move **closer** to the goal
- ▶ Visit the node whose **distance to the goal** is **minimal**
- ▶ Doesn't handle **dead ends** well
- ▶ Not guaranteed to find the **shortest** path

Dijkstra's algorithm

- ▶ Let $g(x)$ be the distance of the path found from the start to x
- ▶ Choose a node that minimises $g(x)$
- ▶ Needs to handle cases where a shorter path to a node is discovered later in the search
- ▶ **Is** guaranteed to find the shortest path
- ▶ ... but is not the most efficient algorithm for doing so

A* search

- ▶ Let $h(x)$ be an estimate of the distance from x to the goal (as in greedy search)
- ▶ Let $g(x)$ be the distance of the path found from the start to x (as in Dijkstra's algorithm)
- ▶ Choose a node that minimises $g(x) + h(x)$

Properties of A* search

- ▶ A* is **guaranteed** to find the shortest path if the distance estimate $h(x)$ is **admissible**
- ▶ Essentially, **admissible** means it must be an **underestimate**
 - ▶ E.g. straight line Euclidean distance is clearly an underestimate for actual travel distance
- ▶ The more accurate $h(x)$ is, the more efficient the search
 - ▶ E.g. $h(x) = 0$ is admissible (and gives Dijkstra's algorithm), but not very helpful
- ▶ $h(x)$ is a **heuristic**
 - ▶ In AI, a heuristic is an estimate based on human intuition
 - ▶ Heuristics are often used to prioritise search, i.e. explore the most promising options first

Tweaking A^*

- ▶ Can change how $g(x)$ is calculated
 - ▶ Increased movement cost for rough terrain, water, lava...
 - ▶ Penalty for changing direction
- ▶ Different $h(x)$ can lead to different paths (if there are multiple “shortest” paths)

String pulling

- ▶ Paths restricted to edges can look unnatural
- ▶ Intuition: visualise the path as a string, then pull both ends to make it taut
- ▶ Simple algorithm:
 - ▶ Found path is $p[0], p[1], \dots, p[n]$
 - ▶ If the line from $p[i]$ to $p[i+2]$ is unobstructed, remove point $p[i+1]$
 - ▶ Repeat until there are no more points that can be removed

Navigation meshes

Pathfinding in videogames

- ▶ A* works on any **graph**
- ▶ But what if the game world is not a graph? E.g. complex 3D environments

Waypoint navigation



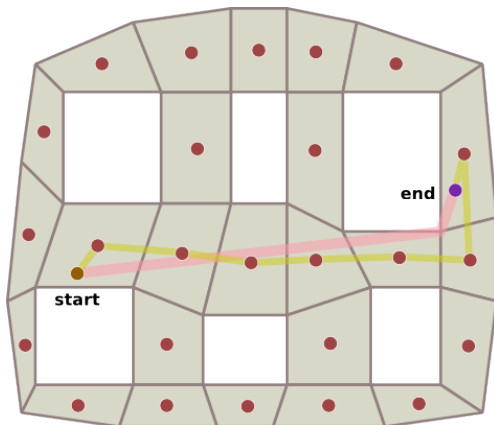
- ▶ Manually place graph nodes in the world
- ▶ Place them at key points, e.g. in doorways, around obstacles
- ▶ Works, but...
 - ▶ More work for level designers
 - ▶ Requires lots of testing and tweaking to get natural-looking results
 - ▶ No good for dynamic environments

Navigation meshes



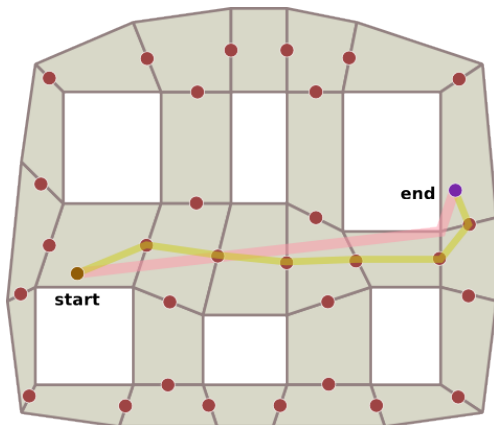
- ▶ Automatically generate navigation graph from level geometry
- ▶ Basic idea:
 - ▶ Filter level geometry to those polygons which are **passable** (i.e. floors, not walls/ceilings/obstacles)
 - ▶ Generate graph from polygons

Meshes to graphs



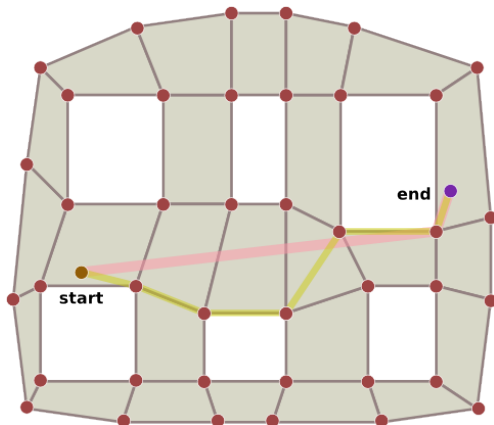
Centres of polygons

Meshes to graphs



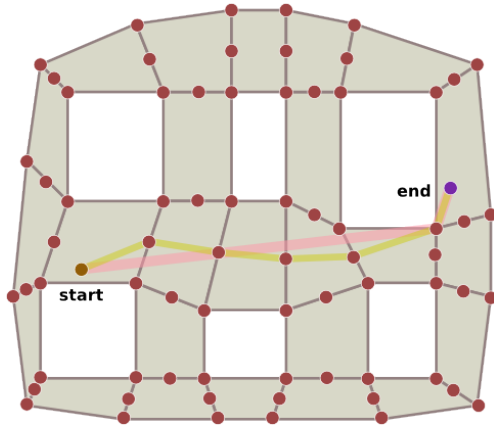
Centres of edges

Meshes to graphs



Vertices of polygons

Meshes to graphs



Hybrid approach: edges and vertices

Following the path

- ▶ **Funnelling:** like string pulling but for navigation meshes
 - ▶ <http://digestingduck.blogspot.co.uk/2010/03/simple-stupid-funnel-algorithm.html>
 - ▶ <http://jceipek.com/Olin-Coding-Tutorials/pathing.html>
- ▶ **Steering:** don't have your AI agent follow the path exactly, but instead try to stay close to it
- ▶ **Dynamic environments:** may need to re-run pathfinder if environment changes (e.g. movable obstacles, destructible terrain)

The travelling salesman problem

The travelling salesman problem (TSP)

- ▶ Classic problem in Computer Science
- ▶ We have a **graph**
- ▶ From starting node S , find the **shortest possible path** that visits every node **exactly once** and returns to S
- ▶ Many real-world applications
 - ▶ Transport and logistics
 - ▶ Manufacturing
 - ▶ Playing Pac-Man
 - ▶ Pub crawls

(<http://www.math.uwaterloo.ca/tsp/pubs/>)

Solving TSP

- ▶ TSP is **NP-complete**
 - ▶ If $P \neq NP$, then there is **no** polynomial-time algorithm for solving it
- ▶ Entire research field devoted to finding efficient **search algorithms** and **heuristics**

MicroRTS

Getting started

- ▶ We now have **Java** in this room (thanks Paul!) but **Eclipse** needs to be installed per-user
- ▶ Download from
`https://www.eclipse.org/downloads/`
- ▶ Run the installer
- ▶ Select **Eclipse IDE for Java Developers**
- ▶ Set the installation folder to somewhere on the D: drive, for example `D:\eclipse`
- ▶ Now go to `https://github.com/falmouth-games-academy/comp250-bot` and follow the instructions