# A.I. in Game Development

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# Academia vs Practice

- Academic research is always a few steps ahead
- Games use techniques which are known in academia for a while, but can't be integrated for various reasons
  - Resources, Feasibility, Game Design
- Gradually new techniques get adopted
  - And games using new techniques get lots of recognition

# Using AI Techniques in games

- Maze Generation
- Navigation
- Goal Selection
- Tactical AI
- Evolution of Intelligent Agents


Saving...
Level 2
207
1
Iron Ration


10/12
091
79
[CROWN OF DESTINY]

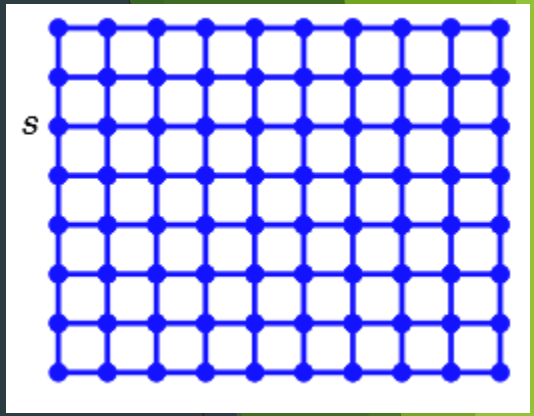

00
00
00

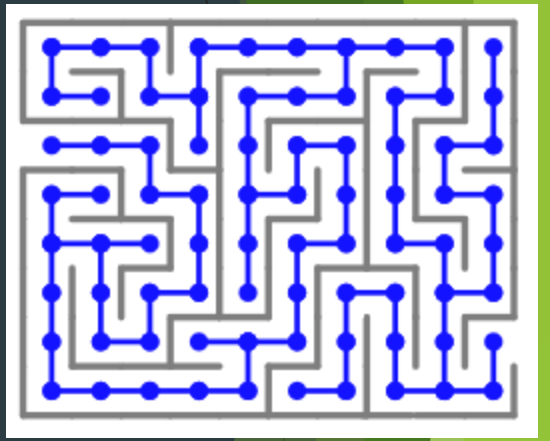
# Maze Generation

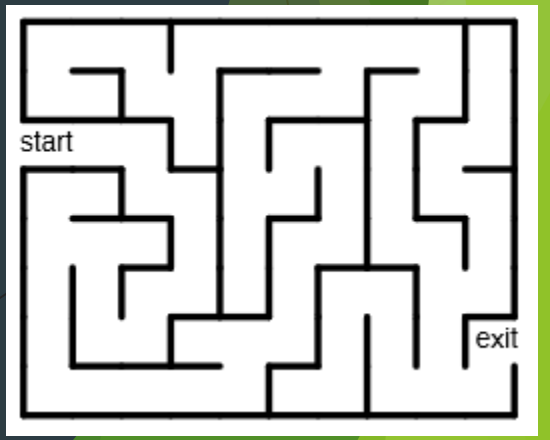
- Why?
  - Procedural Generated Content
  - Randomized level each time you play
  - Infinite replayability
- How?
  - Randomized Depth First Search

# The Algorithm

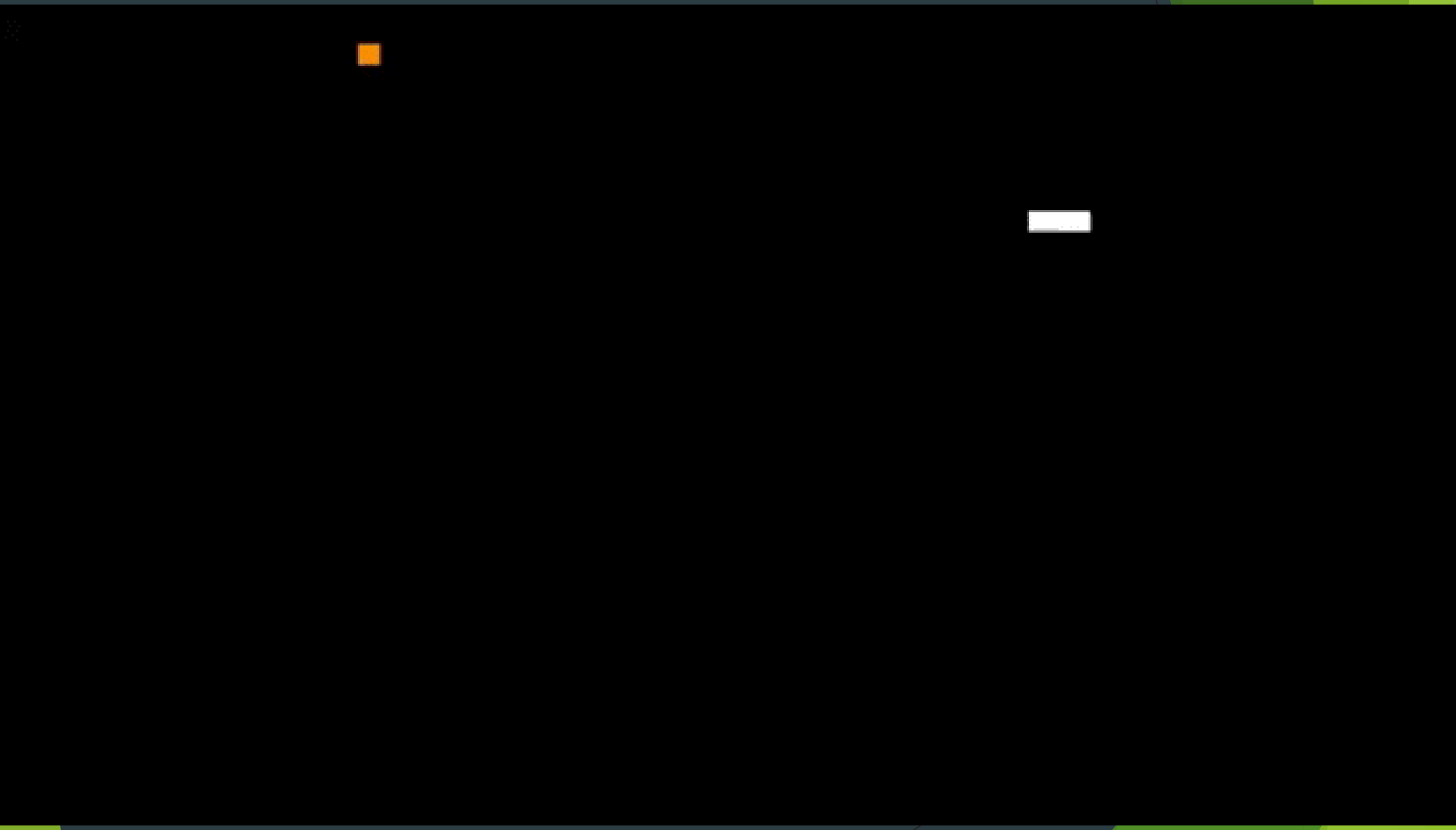
- Start with a large grid of cells, each cell has 4 walls.
- Select starting cell
- Repeat
  - Select random unvisited neighbor
  - Remove the ‘wall’ between them
    - Recurse with the new cell
  - If no unvisited neighbors remain, return
- The maze is generated





# Maze Generation



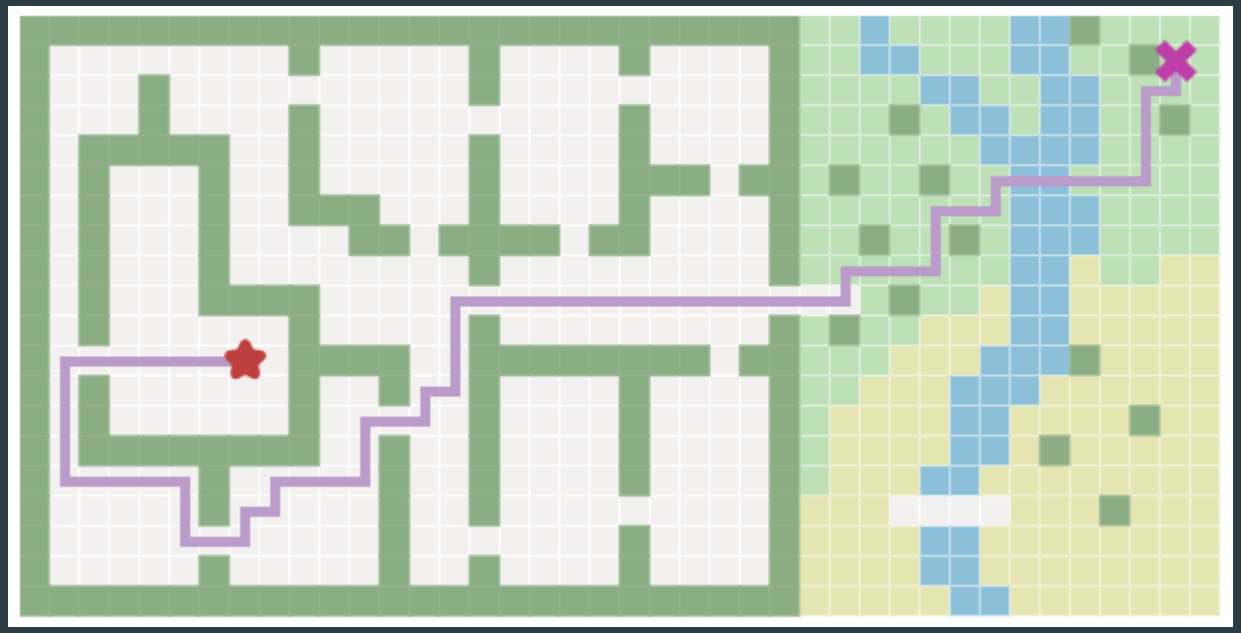
# Maze Generation – in Minecraft

# Navigation

# Navigation & Pathfinding

- How do creatures move in the world?
  - Unit movement in Strategy games
  - Enemy movement in First Person Shooters
  - Any kind of entity moving in almost any kind of game
- A* most popular pathfinding algorithm
  - Represent the map of the world as a graph
  - For now, assume we have a grid
- Case Study: Starcraft

# A* Pathfinding

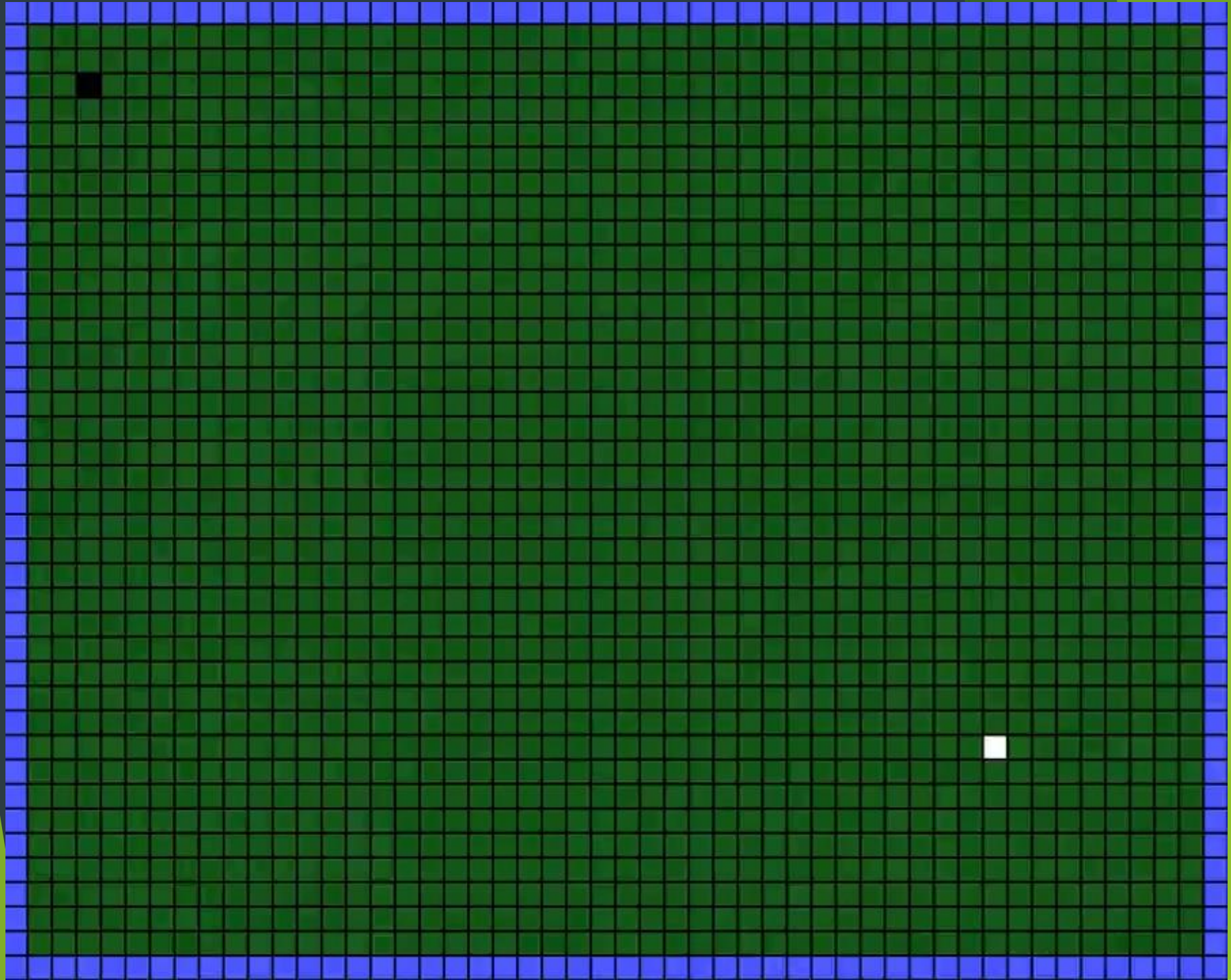


# A* Pathfinding

INTERACTIVE DEMO

(if internet works)

http://www.redblobgames.com/pathfinding/a-star/introduction.html



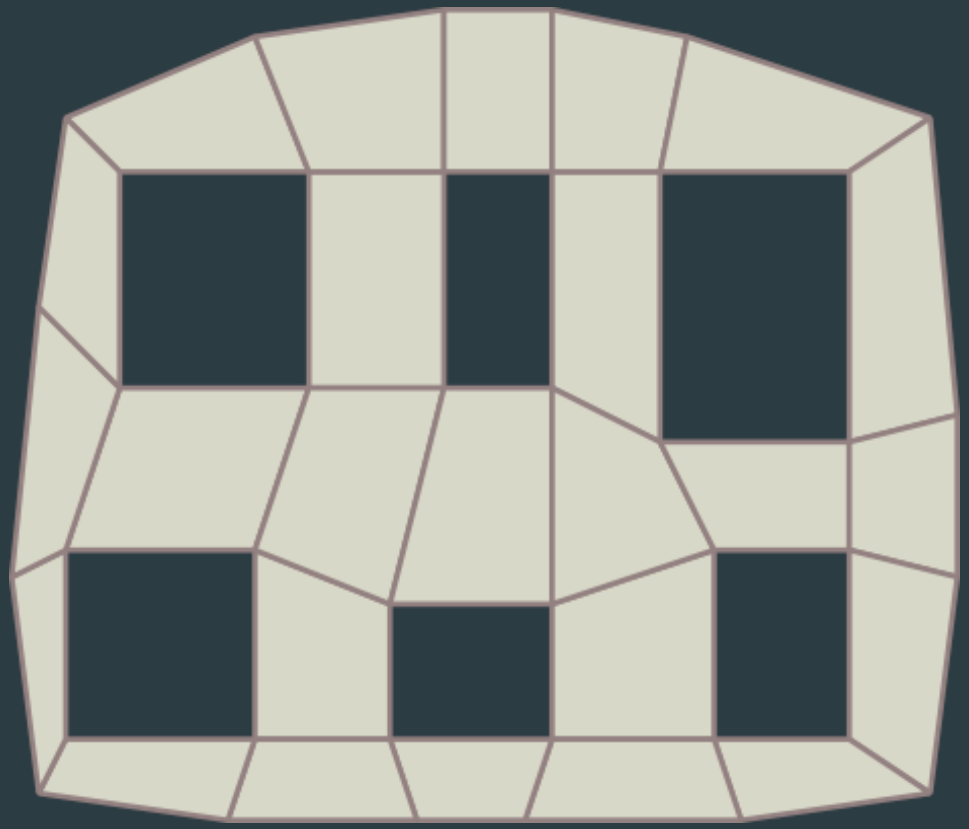
# A* Pathfinding

- *“But wait, grids? That’s so ‘80s!!!”*

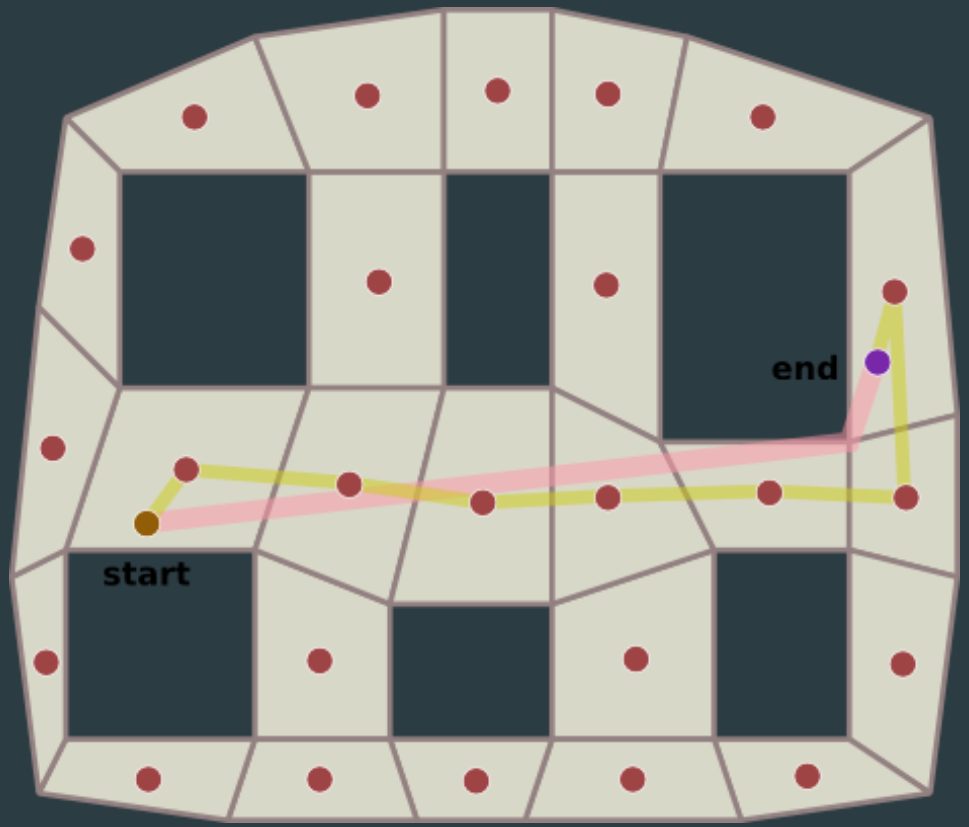
# Extending A*

- Navigation Meshes
- Hierarchical A*

# A* Navigation Meshes



# A* Navigation Meshes



# A* Navigation Meshes

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# Hierarchical A* - Starcraft

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- 1.048.576 pathfinding cells
  - Each cell is 8 pixels wide
- 200 units per player
- 4 players

- LOTS of time and computations

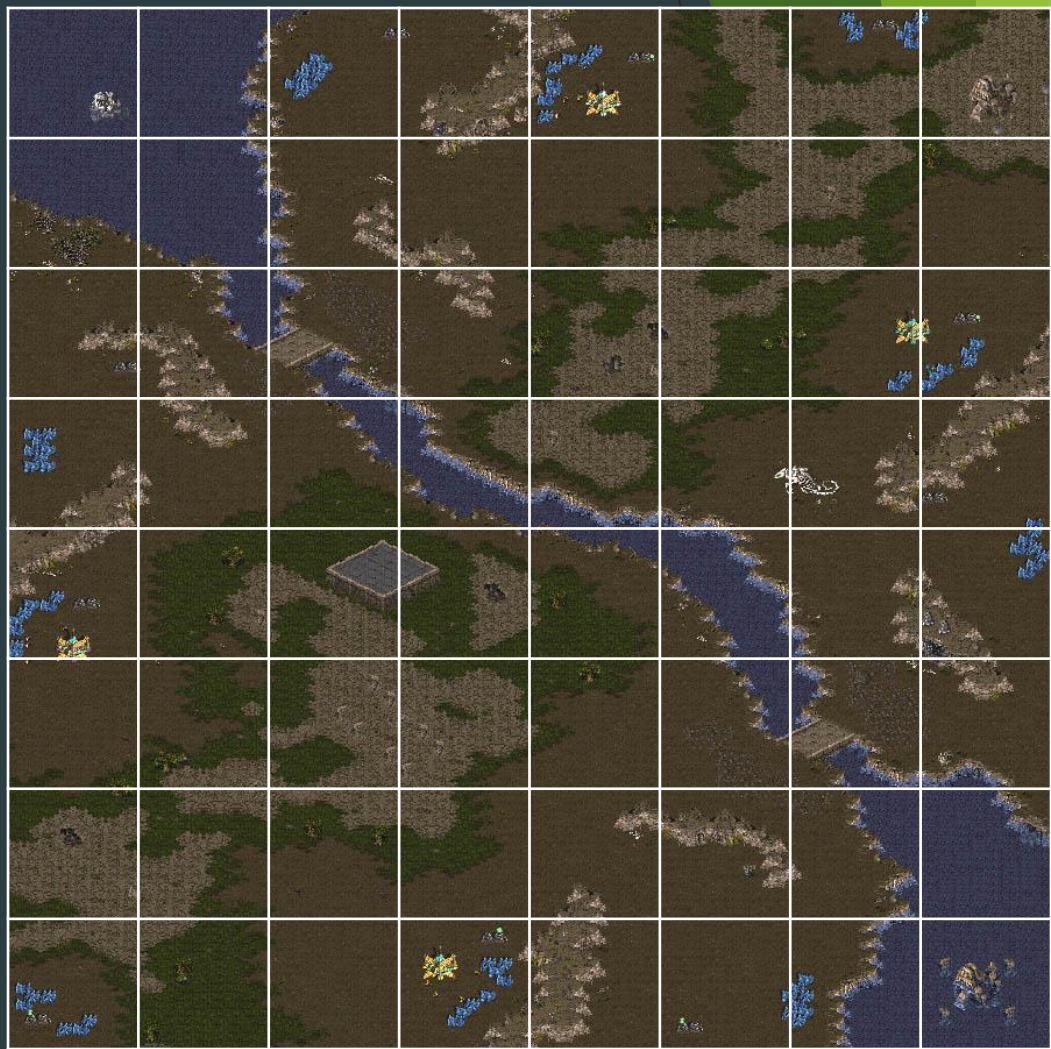
# Hierarchical A* - Starcraft

Solution

- Split region in big cells
- Compute adjacency data
- Run A* on big cells

For individual units

- Run A* only inside the small cell



# Starcraft Pathfinding Video

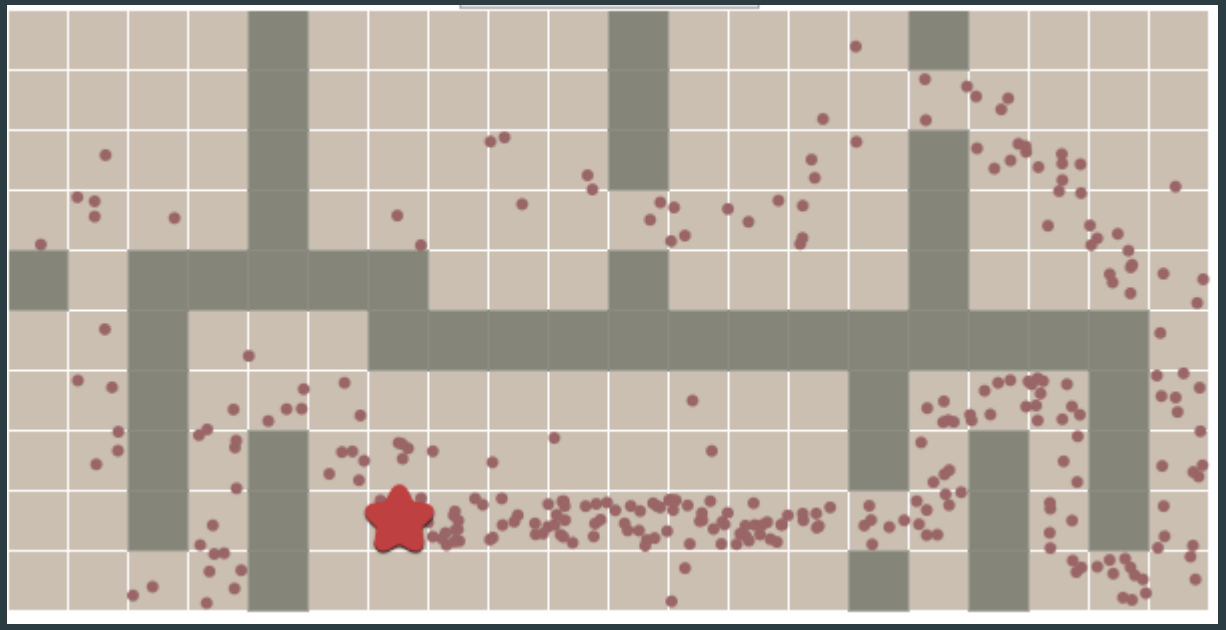
# Bonus: Starcraft Anecdote

- We don’t always want perfect A.I.
- Harvesters using AI were getting stuck in each other

- Solution: Temporary disable pathfinding and collisions

# Bonus: A* vs BFS

- Most advanced algorithm is not always the best
- Tower Defense Games
  - Multiple enemies are moving around an environment towards your base
  - They must avoid turrets and defenses you've built
- Simple solution: Apply A* on all units
  - For each unit, search a path towards player's base
  - Expensive, inefficient
- Elegant Solution: Breadth First Search



# Action Selection

# Action Selection

- How does an entity decide what to do next?
  - Any simulation game
- Case Study: The Sims
  - Autonomous agents simulating humans
  - Lots of objects to interact with in the environment

# The Sims

# The Sims

- A sim is modeled after real humans
  - Trait
  - Needs
  - Emotions
- A sim must do various activities
  - Eat, sleep, cook, work, learn, watch boring AI presentation, play
- A sim must interact with lots of objects and people
  - Bed, fridge, stove, car, books
  - Thief, policeman, teacher, mother, boyfriend, children
- How does a sim, left on his own decide what to do?
  - Greedy Selection

# The Data

## The Sim

- Traits

  shy, playful, serious, romantic

- Needs

  hunger, hygiene, social, fun

  vary in time based on what happens

- Others

  Skill Level, Emotion, etc

## Objects

- Actions
- Needs Satisfied
- Traits that influence

# Smart Objects

- An objects contains all information about it
  - what interactions are available
  - What needs they can satisfy
  - What animations to use
- Example: A Toilet
  - Use Toilet: +20 hygiene, +20 comfort,
  - Clean Toiler: +20 environment, -30 fun, -10 social

# Making a decision

- Look at all the objects around, and analyse
  - The **actions** available on each object.
  - The **reward** provided by each action.
  - The **distance** to the object.
  - The **level of need** felt by the actor at the time.
- Greedy
  - order actions by the value they bring
  - from top N actions, choose one randomly

# Example: “Happyscape”

# Example: “Happyscape”

Eat from Fridge

+ 30 hunger

Play Pinball

+ 40 fun, -10 social

+10 if ‘playful’

Play Chess

+30 fun

+30 if ‘serious’

Talk with Ana

+ 30 social, +10 fun

+5 if ‘romantic’

Clean Fridge

+10 hygiene, -40 fun, -20 social

+50 if ‘clean obsession’

- 40 if ‘lazy’


Johnny

playful, romantic

hunger: 90

social: 60

boredom: 50

hygiene: 10

# Example: “Happyscape”

Value of an action:

**sum(benefit * level of need)**


Johnny

- playful, romantic
- hunger: 90
- social: 60
- boredom: 50
- hygiene: 10

# Example: “Happyscape”

Eat from Fridge = 2700

+ 30 hunger * 90

Play Pinball

+ 40 fun, -10 social

+10 if ‘playful’

Play Chess

+30 fun

+30 if ‘serious’

Talk with Ana

+ 30 social, +10 fun

+5 if ‘romantic’

Clean Fridge

+10 hygiene, -40 fun, -20 social

+50 if ‘clean obsession’

- 40 if ‘lazy’


Johnny

playful, romantic

**hunger: 90**

social: 60

boredom: 50

hygiene: 10

# Example: “Happyscape”

Eat from Fridge

+ 30 hunger

Play Pinball = 1900

+ 40 fun * 50, -10 social * 60

+10 if ‘playful’ * 50

Play Chess

+30 fun

+30 if ‘serious’

Talk with Ana

+ 30 social, +10 fun

+5 if ‘romantic’

Clean Fridge

+10 hygiene, -40 fun, -20 social

+50 if ‘clean obsession’

- 40 if ‘lazy’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social: 60

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hygiene: 10

# Example: “Happyscape”

Eat from Fridge

+ 30 hunger

Play Pinball

+ 40 fun, -10 social

+10 if ‘playful’

Play Chess = 1500

+30 fun * 50

+30 if ‘serious’

Talk with Ana

+ 30 social, +10 fun

+5 if ‘romantic’

Clean Fridge

+10 hygiene, -40 fun, -20 social

+50 if ‘clean obsession’

- 40 if ‘lazy’


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# Example: “Happyscape”

Eat from Fridge

+ 30 hunger

Play Pinball

+ 40 fun, -10 social

+10 if ‘playful’

Play Chess

+30 fun

+30 if ‘serious’

Talk with Ana = 2600

+ 30 social * 60, +10 fun * 50

+5 if ‘romantic’ * 60

Clean Fridge

+10 hygiene, -40 fun, -20 social

+50 if ‘clean obsession’

- 40 if ‘lazy’


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# Example: “Happyscape”

Eat from Fridge

+ 30 hunger

Play Pinball

+ 40 fun, -10 social

+10 if ‘playful’

Play Chess

+30 fun

+30 if ‘serious’

Talk with Ana

+ 30 social, +10 fun

+5 if ‘romantic’

Clean Fridge = -3100

+10 hygiene * 10, -40 fun * 50, -20 social * 60

+50 if ‘clean obsession’

- 40 if ‘lazy’


Johnny

playful, romantic

hunger: 90

social: 60

boredom: 50

hygiene: 10

# Example: “Happyscape”

Value of an action:

sum(benefit * level of need)

| | |
|---|---|
| Eat from Fridge | 30 * 90 = 2700 |
| Play Pinball 60 | (40+10) * 50 – 10 * |
| | = 1900 |
| Play Chess | 30 * 50 = 1500 |
| Talk with Ana | (30+5) * 60 + 10*50 |
| | = 2600 |
| Clean Fridge 60 | 10 * 10 – 40*50 – 20 * |
| | = -3100 |


Johnny

playful, romantic

hunger: 90

social: 60

boredom: 50

hygiene: 10

# Example: “Happyscape”

Value of an action:

**sum(benefit * level of need)**

| | |
|---|---|
| Eat from Fridge | 2700 |
| Talk with Ana | 2600 |
| Play Pinball | 1900 |
| Play Chess | 1500 |
| Clean Fridge | -3100 |


Johnny

- playful, romantic
- hunger: 90
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- boredom: 50
- hygiene: 10

# Example: “Happyscape”

# “Happyscape”

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# Tactical AI

# Tactical AI

- What's the best way to compete with an enemy?
  - Strategy games, RPGs, competitive games
- Case Study: Total War
  - Strategy Game knows for great AI

# Total War

# Video of a Battle

# Total War Series

A.I. happens at different levels

- Unit Level
- Squad / Battle Level
- Strategy Level

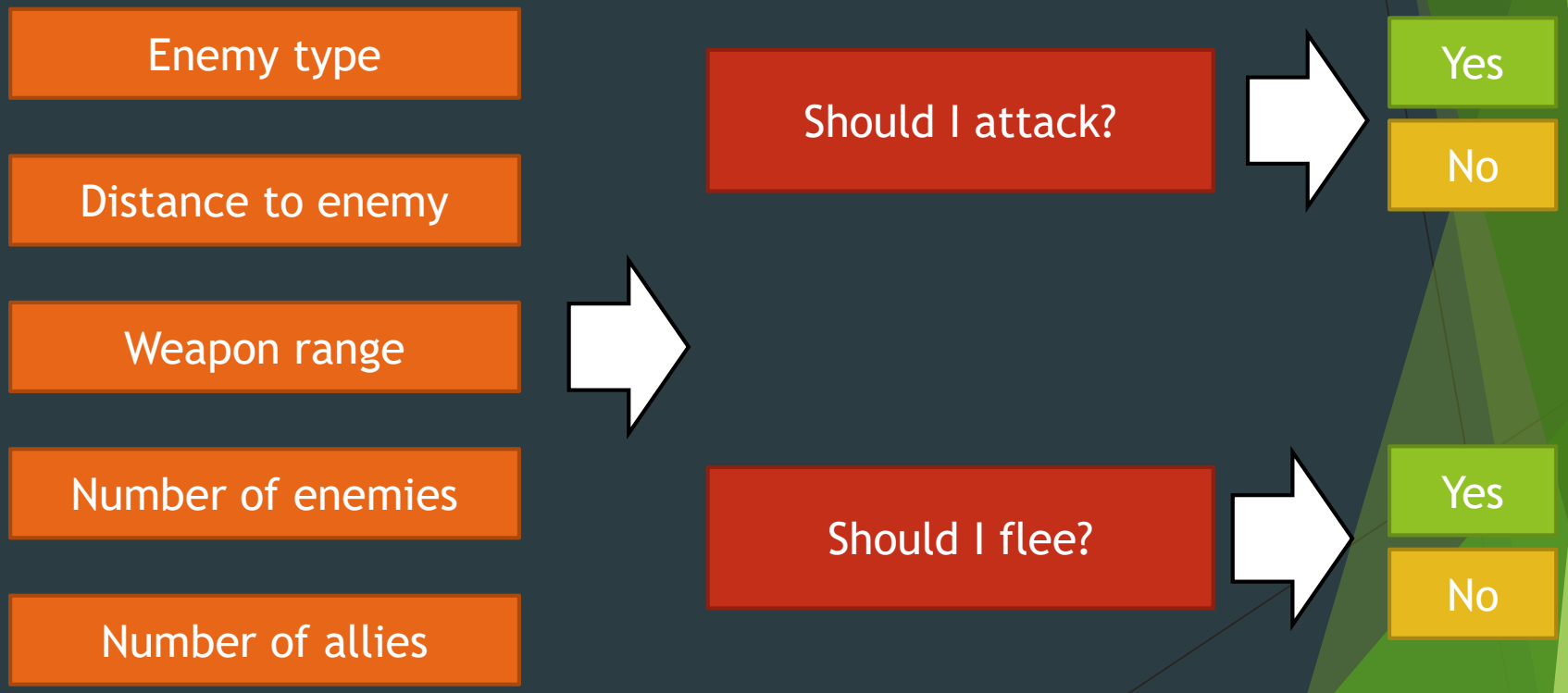
# Unit Level

# Total War

Unit Level

- Manages behavior of individual unit
- What to do? Who to attack? Where to go?
- Simplified ‘neural network’
- A mini-network for each action
  - attack, defend, flee
  - Output is ‘Yes’ or ‘No’ based on several inputs

# Total War


Enemy type
Distance to enemy
Weapon range
Number of enemies
Number of allies
Should I attack?
Should I flee?
Yes
No
Yes
No

# Squad Level

# Total War

Squad Level

- Tactics and Reactions
- If-Then rule-based system
- Rules taken out of *Sun Tzu's The Art of War*
  - If you outnumber the enemy 10:1 then **split and surround** them.
  - If you outnumber the enemy 5:1 then **attack** them directly.
  - If you outnumber the enemy 2:1 then **divide** them up.
- Group Pathfinding and Formations
  - A* used for squads
  - Individual units don't search for paths, but stay at a certain offset from squad centre
  - Individual logic only for local avoidance

# Total War

## Emergent Behavior

- Rules at individual and squad levels interact and lead to patterns
- Example: Incoming Cavalry attack a squad of Archers
  - Individuals neural networks tell it to scared and flee (edge troops)
  - Squad size decreases -> Squad Logic must react
  - Squad might get split in two based on rules reasoning
- Whole armies can be split and scared by weaker opponents that flank them

# Strategy Level

# Total War

Strategy Level

- Turn based top-level strategy
- Genetic Algorithms used to ‘evolve’ the virtual strategists
- Several temperaments and skills modelled based on a set of traits
- Variety in strategy used by opponents
- Evolve over time
  - ‘Natural Selection’ also results from interacting with the Player

# Total War – Genetic Algorithm

## Chromosome

composed of personality traits of a strategist

| | | | | |
|---|---|---|---|---|
| Aggressive | Anger | Ambush | Attacker | Risky Attacker |
| Defender | Diplomat | Builder | Engineering | Espionage |
| Taxman | Trader | Corrupt | Justice | etc. |

## Mutations

New generation of strategists derived from previous successful ones, with small changes to the personalities

## Fitness Function

Success in battle / The territories acquired / richness of the territories / not being killed by the human player

# Bonus: Indirect Control

- Players never control individual units, just indirect control through orders
  - Unit emotions may override orders
  - Challenges players to understand how units function
  - Shows off the A.I.
- Makes opponent A.I. seem more intelligent, since you're both using the same tools

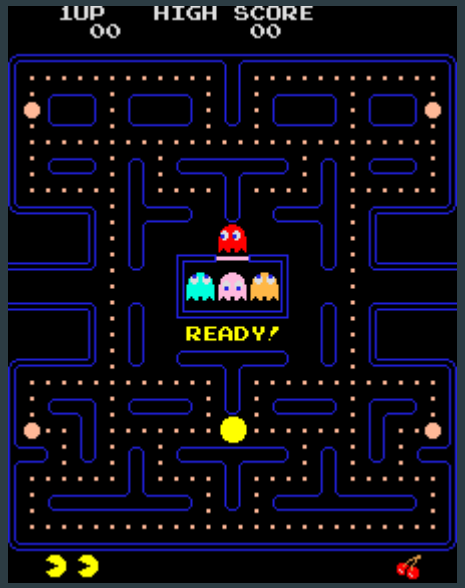
# The evolution of intelligent agents

# Intelligent Agents

- In-game entities that oppose the player
- Must move and make decisions in real-time
- Navigate environment, attack player, hide, take cover, cooperate with other agents
- Must be smart enough to pose a challenge
- Must be dumb enough to be fun

- Arcade, Action, First Person Shooters, etc

# PAC-MAN (1980)



# PAC-MAN (1980)

- Very simple State Machine
  - Scatter, Chase, Frightened, Respawn
- Each ghost has specific behavior rules
  - Red: Aggressive, target PC tile, variable speed
  - Pink: target tile in from of PC, can be tricked
  - Blue: more complex target tile, unpredictable
  - Orange: aggressive if PC is close, otherwise wandering
- Simple Rules lead to complex behaviors
- Clear association between color and behavior -> strategic play
- No randomness -> predictable -> exploitable

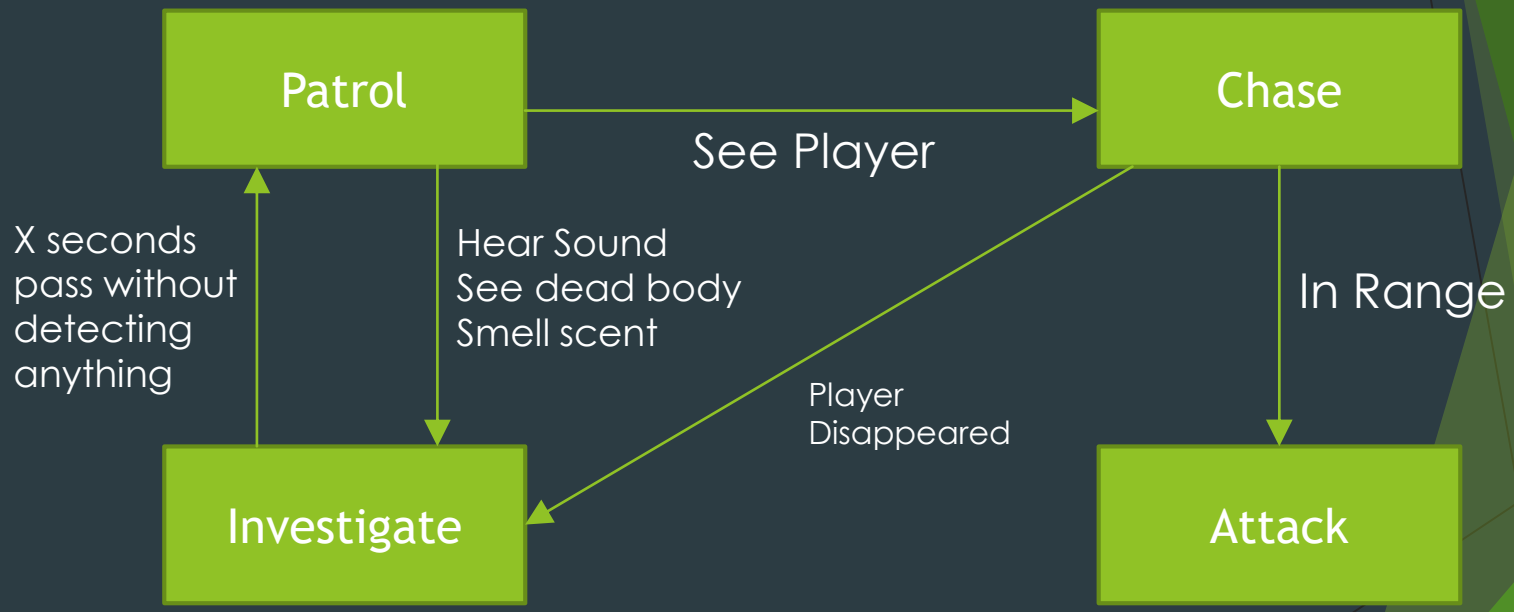
# Thief (1998)

# Thief (1998)

- Was considered revolutionary
- Guard AI was a State Machine, focused on SENSORS

- They **See**, **Hear**, and even **Smell** (as ‘fake sounds’)
  - Vision sensors depends on light, size, distance
  - Sound sensors depend on intensity, distance, walls
  - Context Sensitive Alertness

# Thief State Machine Example



# Thief (1998)

- Need to be kept a bit ‘unintelligent’, to avoid frustration
  - Short memory
  - Speaking to themselves
  - Predictable + small random variations
  - => Easier to fool (which is fun)
- Still a relatively simple FSM, but addition of sensors was a huge evolution

# F.E.A.R (2006)

# F.E.A.R

- Milestone in enemy A.I.
- Agents make plans to attack and subdue the player
- Agents use the environment
- Agents collaborate between them

# F.E.A.R

Agents make plans to attack and subdue the player

- First use of a Task Planner in games
  - Combination between STRIPS and A* for searching a plan
  - Start with a set of all possible actions
  - Computes a sequence of actions to reach a goal
    - Example: Dodge -> Move Closer -> Take Cover -> Ambush -> Kill Enemy
  - Different enemy types have different action sets
    - soldier, assassin, medic
- Huge improvement over FSM, quickly adopted by most games

# F.E.A.R

Agents use the environments

- Environment is filled with Smart Objects
- Smart Objects inform the agent about things he can do
  - Hide, take cover
  - Smash doors, windows
  - Shoot a barrel to make it explode
  - Use a ladder to get to higher position

# F.E.A.R

Agents collaborate between them

- Dynamic Blackboard technique
  - used to store facts about the world
    - *I saw the Player there*
    - *There's a grenade in the next room*
  - allows sharing of information between agents
- Squad Tactics
  - High-level AI logic coordinates multiple individuals
  - Agents communicate and exchange facts about the world
  - Communication is also vocalized for the player to hear

# Other notable techniques

- Decision Tree Learning
- Belief-Decision-Intention System
- Partial-Order Planning
- N-Gram statistical Prediction
- Neural Networks
- Behavior Trees
- Machine Learning

# Conclusions

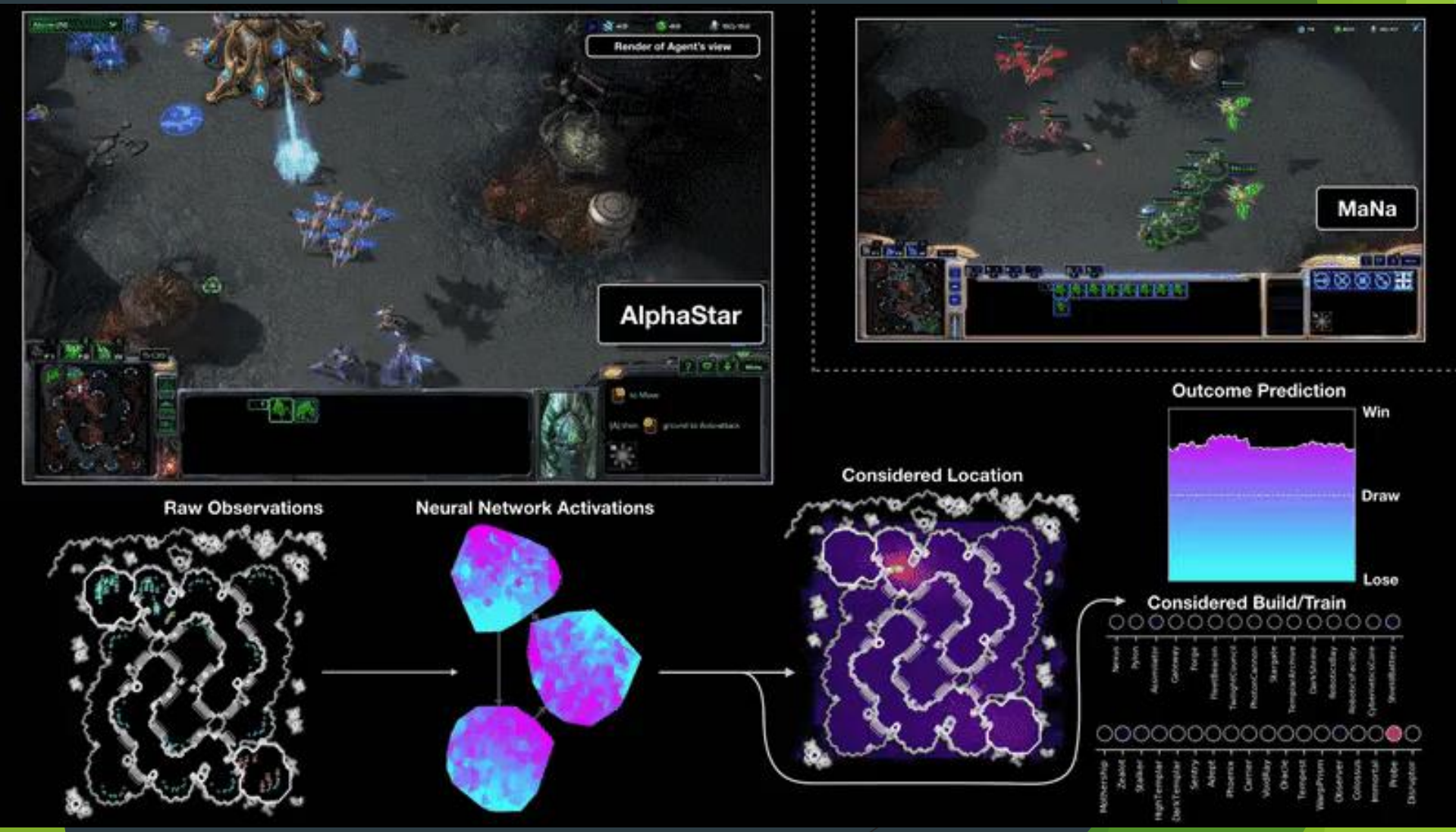
- Lots of cool usages for AI
- Even algorithms that seem insignificant have great uses
- Games that implemented new ways to use AI almost always got recognition
  - Black & White, Fighting Games, Outcast, Fable, Left 4 Dead, Bioshock Infinite

# Extra: Machine Learning

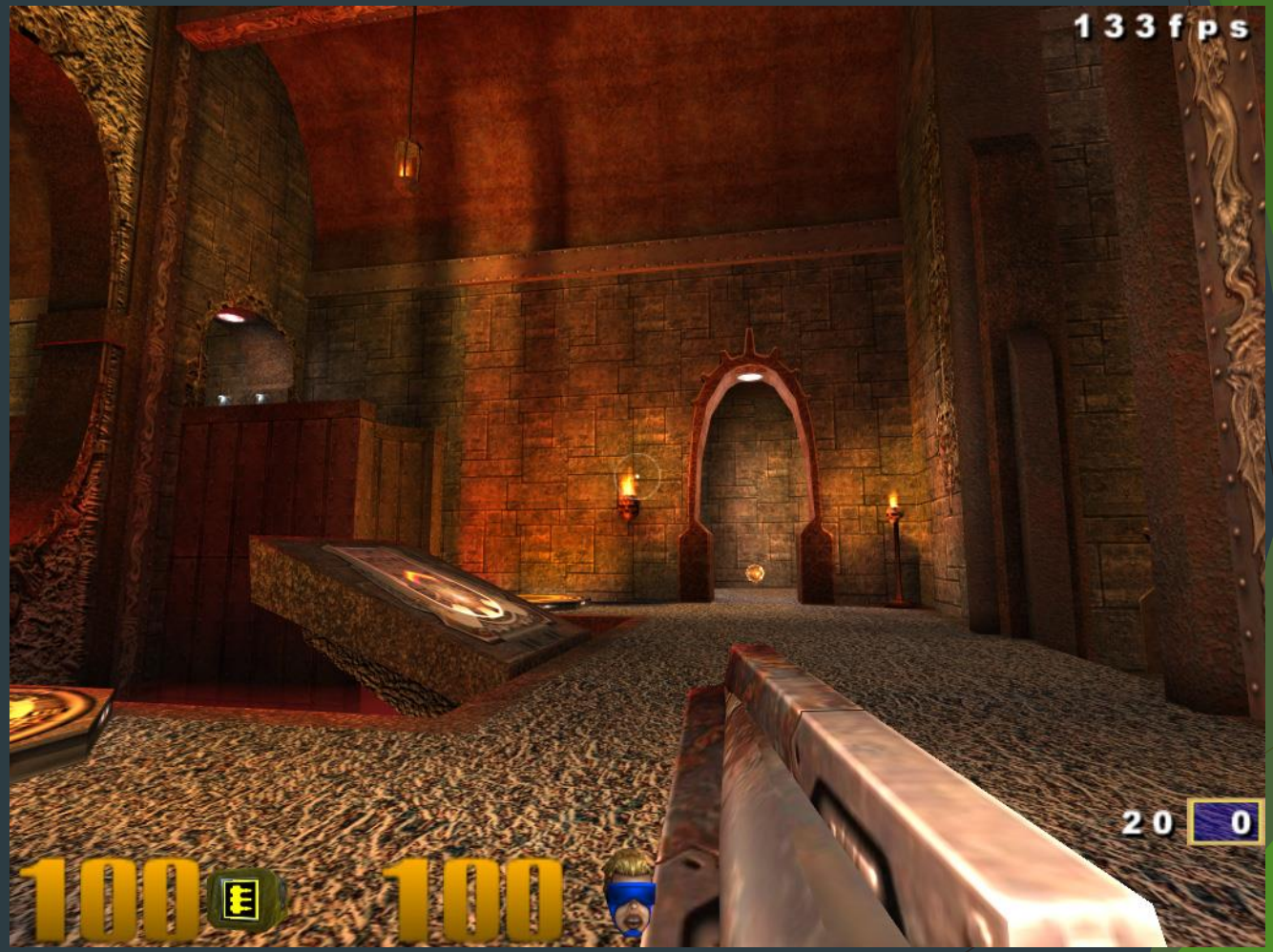
# Deep Learning

- Machine Learning method based on artificial neural networks
- Challenge: Teach a ML machine to play a game as if it were a human
  - No access to game's code
  - Same knowledge and input as a human
- Challenge: Make it beat other humans
- DeepMind, by Alphabet Inc (Google)
- OpenAI (Elon Musk)

# DeepMind: Starcraft 2



# DeepMind: Quake 3 CTF



# OpenAI: DOTA 2

# Questions?