Decision Making: Advanced Planning (Hierarchical Task Networks)

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Announcements

- Assignment 3 due in a week, helper video released on eClass tonight.
- Wednesday we start the Player Modelling section!
- Thursday Lab 5-7:50pm (ETLC E2-002)
- Friday is Quiz 3, covering Behavior Trees, Forward Planning, Backward Planning, Partial Order Planning, and Hierarchical Task Networks (today's lecture) in detail. (Remembering other decision making approaches and path planning will be helpful, but not the focus). Player modelling lightly touched on.

What topic(s) would you be interested in for the Future of Game AI section/quiz? (59 responses)

- **22** suggested topics we have/will cover
- **13** suggested uncovered topics that could make good “Future of Game AI” topics
- **10** suggested uncovered topics that don’t fit this class
- **14** suggested nothing or I didn’t understand the suggestion

22 Topics We Have/Will Cover

- **Specific Game AI implementations**: 10 (Boss AI: 1, Strategy: 2, Children's game: 1, dialogue-based/walking dead: 1, simulation game/FIFA: 1, FPS/MOBA: 1, Dishonored 2 AI: 1, Red Dead Redemption 2: 1)
- **PCG** (WFC): 3
- **Btrees**: 2
- **Planning:** 2
- **Player Modeling** (Personality modeling, Emotion Modelling, Experience Management): 2
- **“Methods involving Randomness like MCTS”**: 1
- **Genetic Algorithms**: 1
- **Dialogue**: 1

13 Uncovered (Good Fit for Future of Game AI) Topics

- **Future of Game AI** (e.g. "So far we've been learning about the history and old methods no longer used (path networks, planning, rules to an extent, etc) but haven't covered anything in the future"): 3
- **Reinforcement Learning in Games**: 2
- **Automated Playtesting**: 2
- **Game AI in Academia**: 1
- **AI for Automated Game Playing**: 1
- **ML for Game Design (my research)**: 1
- **Balancing Game AI**: 1
- **"How AI can change cinematic cutscenes"**: 1
- **Generated dialogue and story**: 1

10 Uncovered Topics (less of a good fit)

- Different Heuristics <-CMPUT 350 Advanced Game Programming
- Other pathing approaches (3)
- Image recognition <-CMPUT 428 Computer Vision
- Augmented Reality for Games
- “Analysis as to how most game engines natively deal with ai pathing and planning” <-CMPUT 414 Intro to Multimedia Tech
- Optimization of Game AI
- "I want to see someone put mario kart ai into a tesla"
- “NPC with higher level thinking and emotions”
- “Something like Siri”

14 N/A Topics or Confusing Topics

- Not sure/Anything/Blank/Gibberish: 12
- "Something like the NPC in game Anime, which [is] more like [a] real human": 1
- Game: 1

List to vote on in a later lecture PQ
8 Uncovered, Good Fit Topics + prior topics

- Reinforcement Learning in Games, Automated Playtesting, Game AI in Academia, AI for Automated Game Playing, ML for Game Design, Balancing Game AI, "How AI can change cinematic cutscenes”, Generated dialogue and story
- AI-based Game Design
- AI for Game Design
- Procedural Content Generation via Machine Learning
- Mixed-initiative PCG (human + AI designing)
- Further discussion on covered topic

POP Algorithm (Reminder)

- Start with initial plan [Start, Finish] where Start can be ordered before Finish
- Pick one **flaw** (open precondition or conflict)
  - Arbitrarily or based on some heuristic
- Generate successor plans for every possible consistent way to resolve flaw
  - Pick plans based on some heuristic
- Stop when solution is reached

Problems Remain

- In all cases so far we have had to replan from scratch every single time we have a new goal or if the world changes
  - This makes it infeasible for quick action
- But you as a person know how to do many things

- Example
  - Travelling to the grocery store doesn’t require a lot of cognitive effort from any of you.
  - If there is traffic/construction, *then* adjust

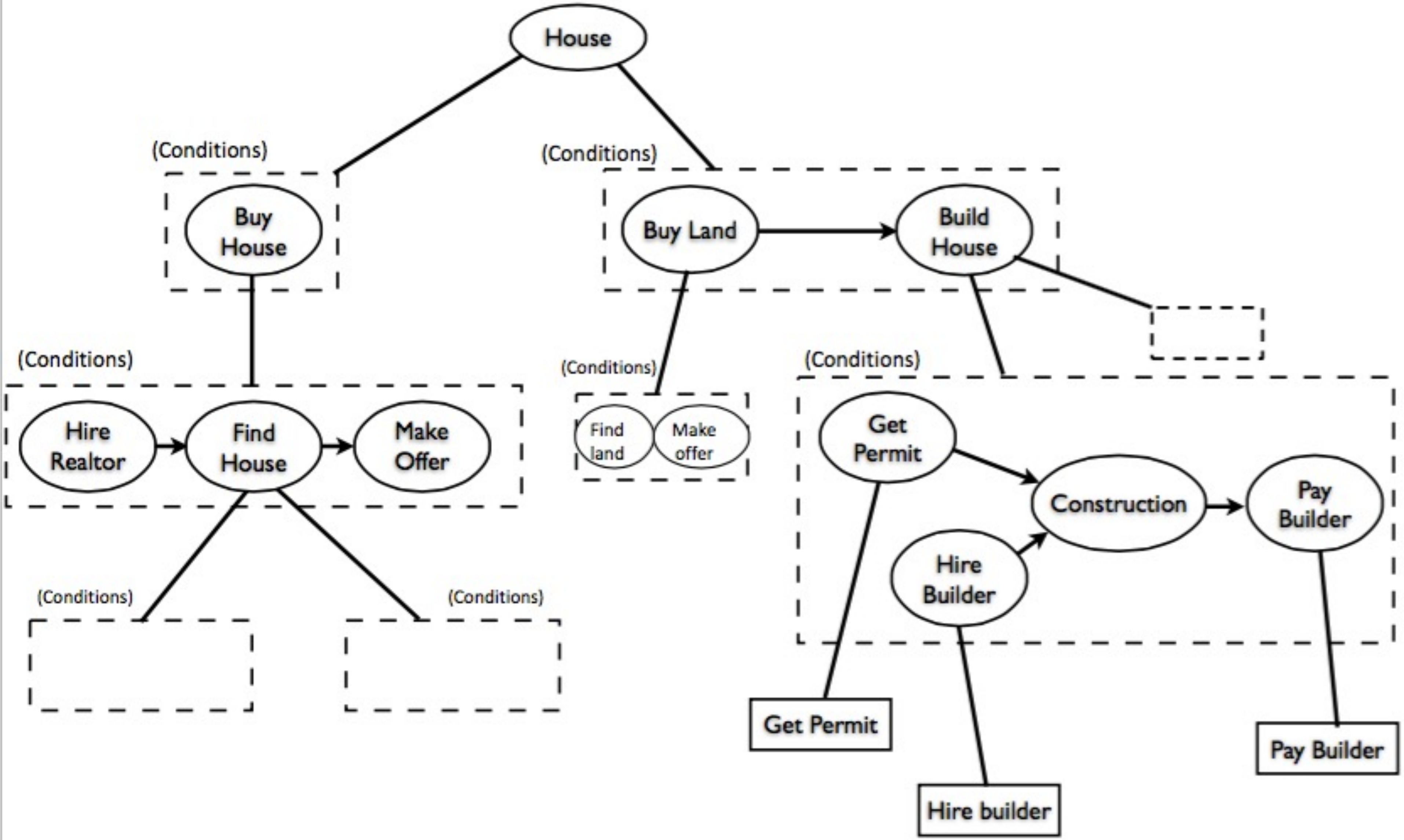
Example: F.E.A.R.

- F.E.A.R AI **(warning a lot of blood**): https://youtu.be/abkDwSDfjqY?t=272 (4:32 to 6:30)

- Designed by Dr. Jeff Orkin, F.E.A.R.'s AI made use of a hierarchical planner to adapt intelligently to the player
- Also used in the Killzone series (more on that in a bit) and recently in Square Enix's "Left Alive"

Hierarchical Task Networks

- Hierarchical decomposition of plans
- Initial plan describes high-level actions
  - E.g. “Build House”, “Find Player”, etc
- Iterate along the current top level of the plan.
- Recursively solve all the way down to “primitive” or “atomic” actions (”move to x,y”) until one part of the plan is done, then move on.


House
(Conditions)
Buy House
(Conditions)
Buy Land
Build House
(Conditions)
Hire Realtor
Find House
Make Offer
(Conditions)
Find land
Make offer
(Conditions)
Get Permit
Construction
Pay Builder
Hire Builder
(Conditions)
(Conditions)
Get Permit
Hire builder
Pay Builder

```
Given state s, Tasks T, Domain D
Let P = empty plan
Let $T_0 = \{t \in T \mid \text{no task comes before } t\}$
Loop
    If $T_0$ is empty, return P
    Pick any $t \in T_0$
    If t is primitive
        Modify s according to effects
        Add t to P
        Update T by removing t
        $T_0 = \{t \in T \mid \text{no task comes before } t\}$
    Else
        Let M = a method for t with true preconditions in state s
        If M is empty return FAIL
        Modify T: remove t, add subtasks of M (note order constraints)
        If M has subtasks
            $T_0 = \{t \in \text{subtasks} \mid \text{no task comes before } t\}$
        Else
            $T_0 = \{t \in T \mid \text{no task comes before } t\}$
Repeat
```

HTN Planner

- Each “task” segments the planning problem into smaller and smaller problems
- Only plan out the high-level plan at first
  - Replan if conditions break it
- Only plan out primitive actions of the current high-level task.

- *Note*: can use any of the other three planning algorithms discussed for primitive action planning

Why HTNs?

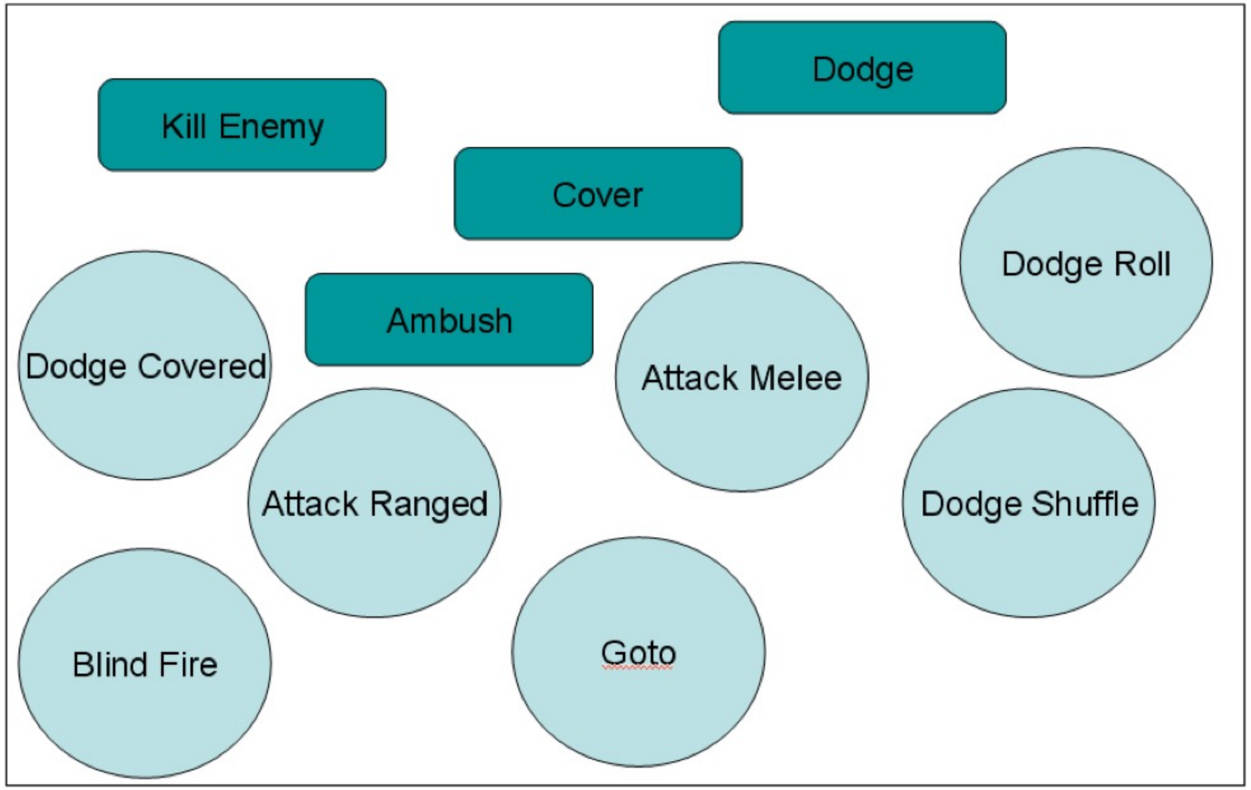
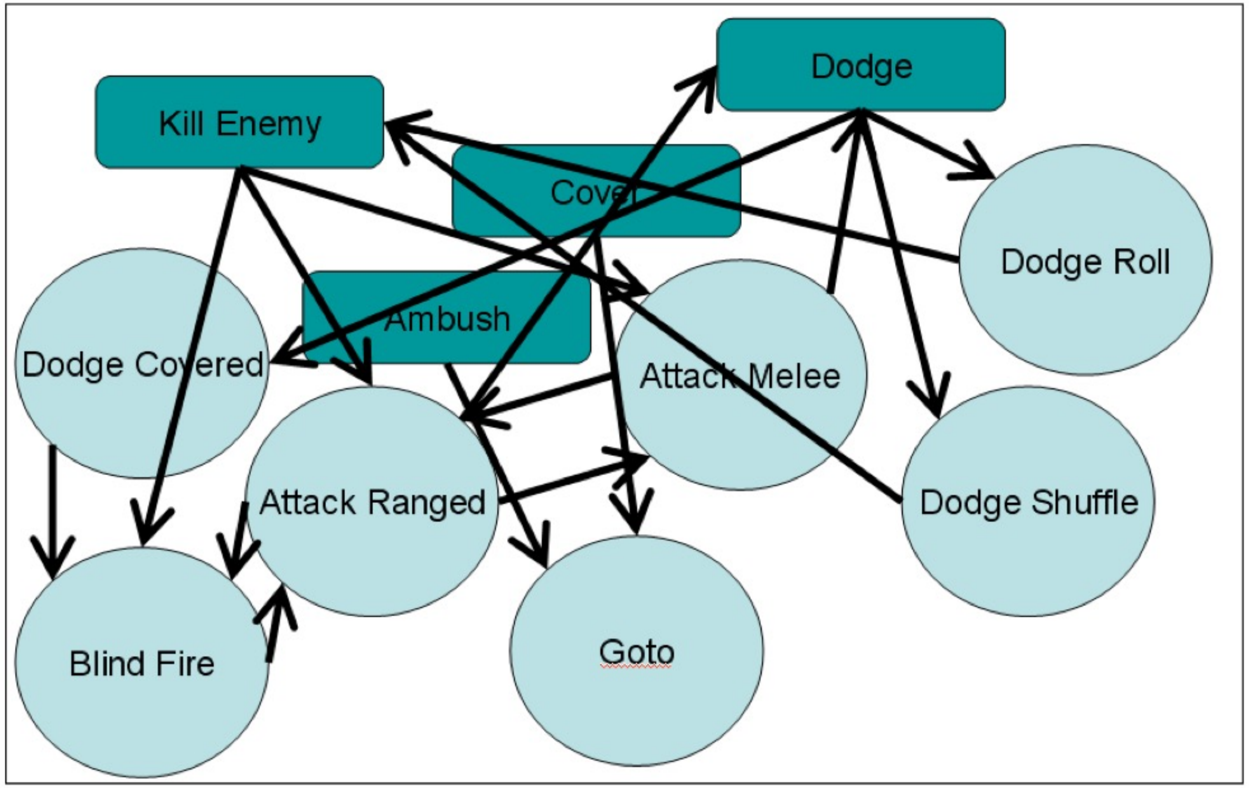


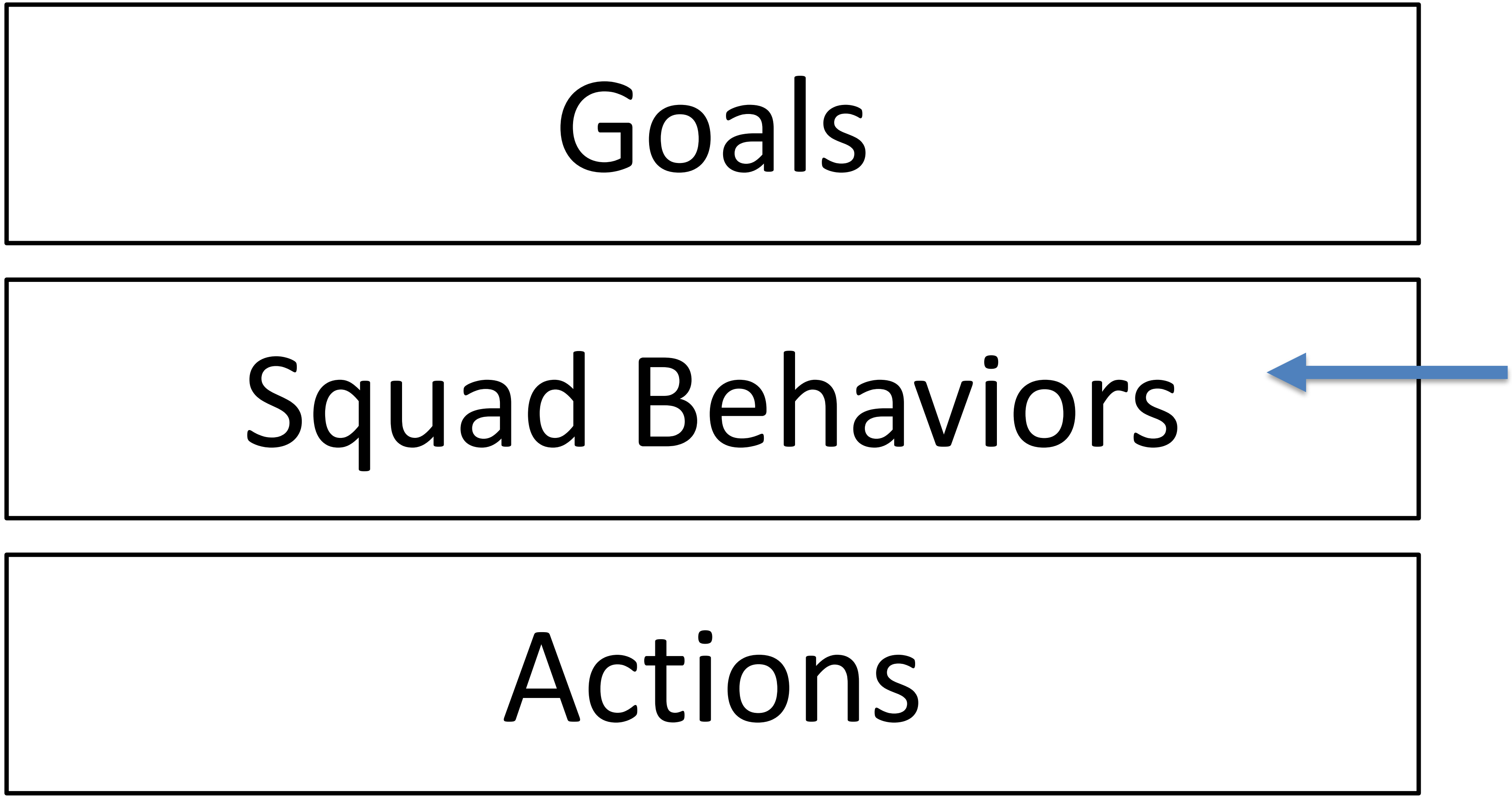
Figure 6: We do this.



But we never have to do this.

http://alumni.media.mit.edu/~jorkin/gdc2006_orkin_jeff_fear.pdf

FEAR Implementation



Goals

Squad Behaviors

Actions

Ignoring this for now

3 Different FEAR AI Entities

“Soldier”

Assassin

Rat

Basic FEAR AI Setup

3D Model Animations

Goals

Squad Behaviors

HTN Actions

Basic FEAR AI Setup

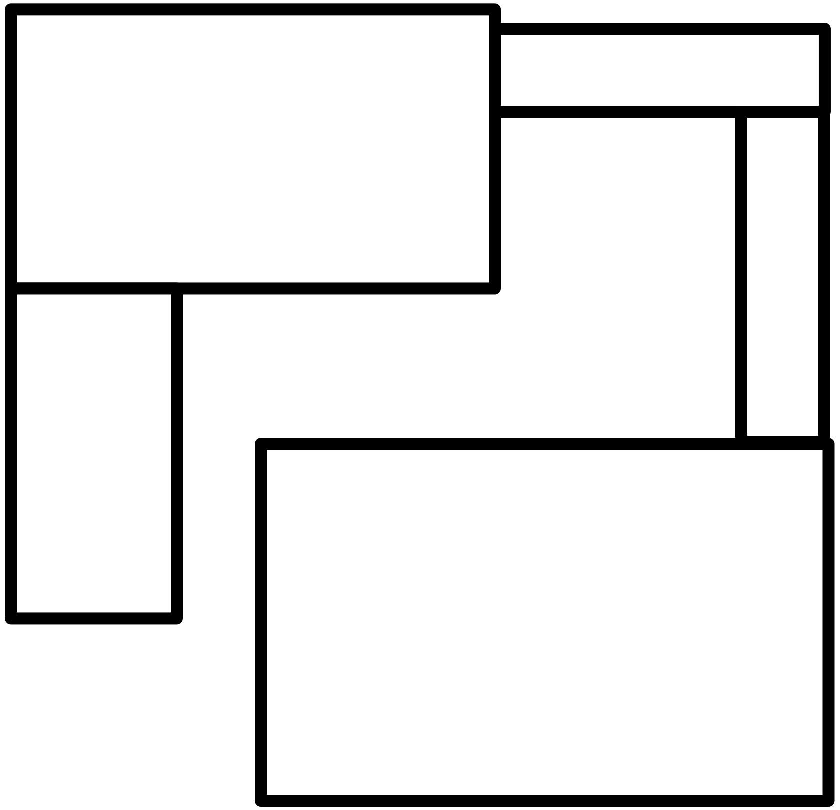
World_State:

-Contains everything currently true about the world.

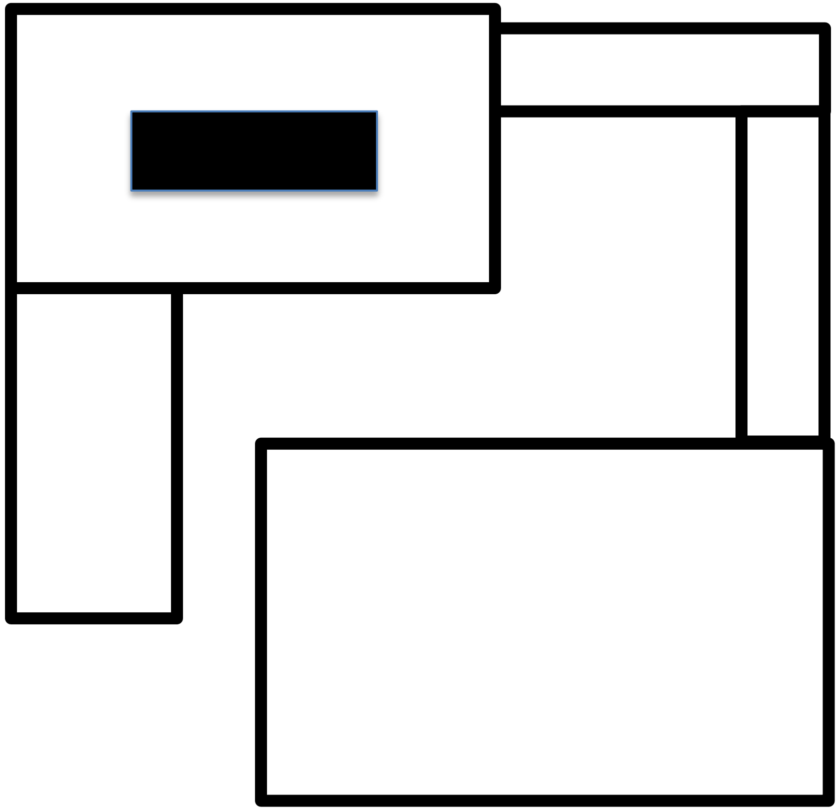
A* Planner:

-Given a start and goal find if there is a legal plan.

Current Level:

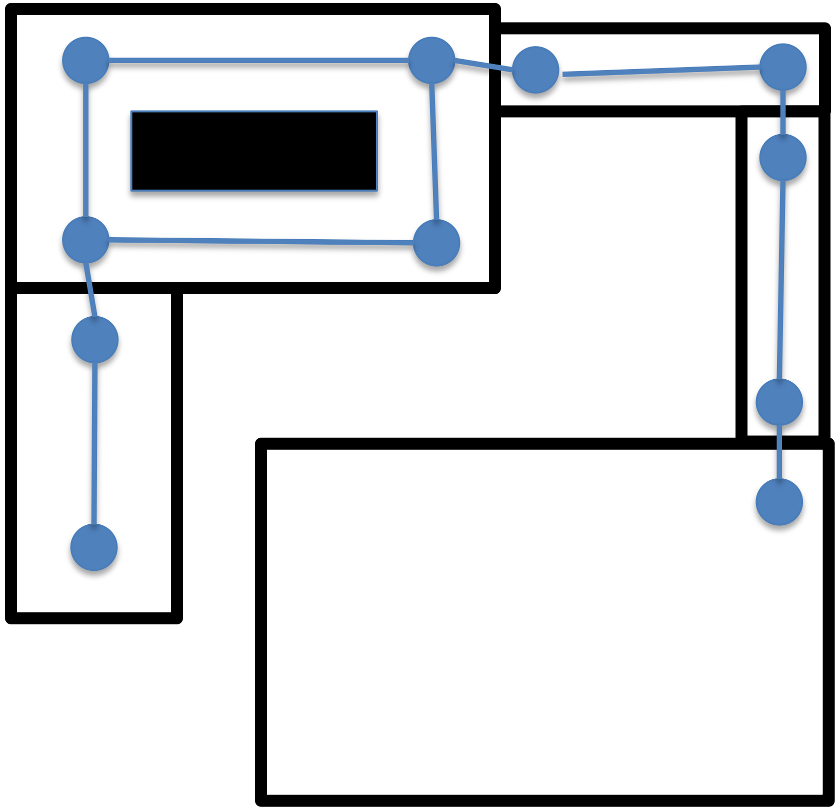


Level



Level

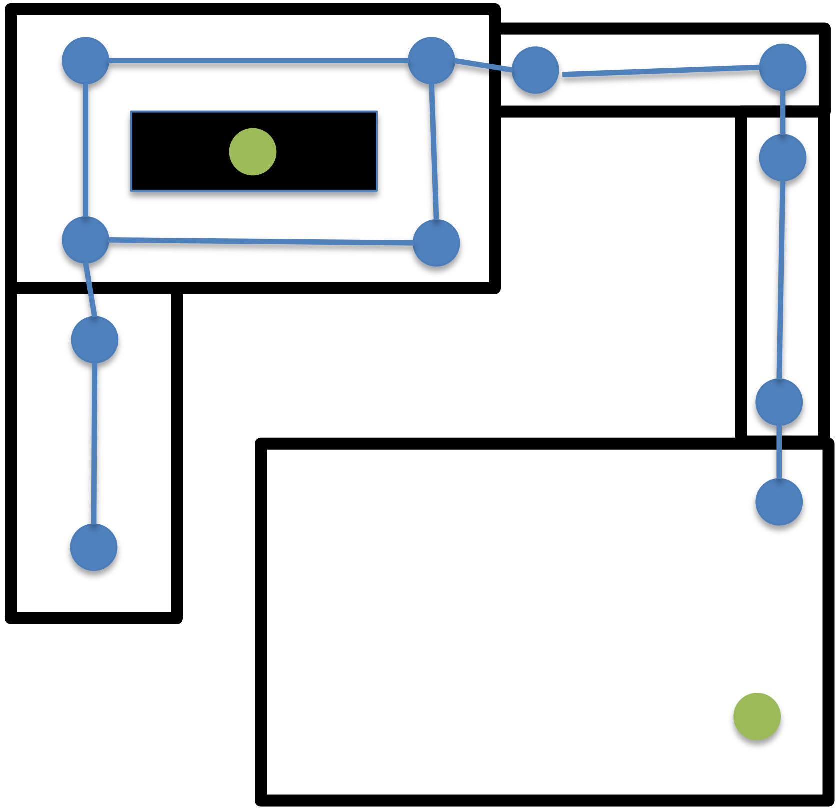
Nodes



Level

Nodes

Smart Object Nodes

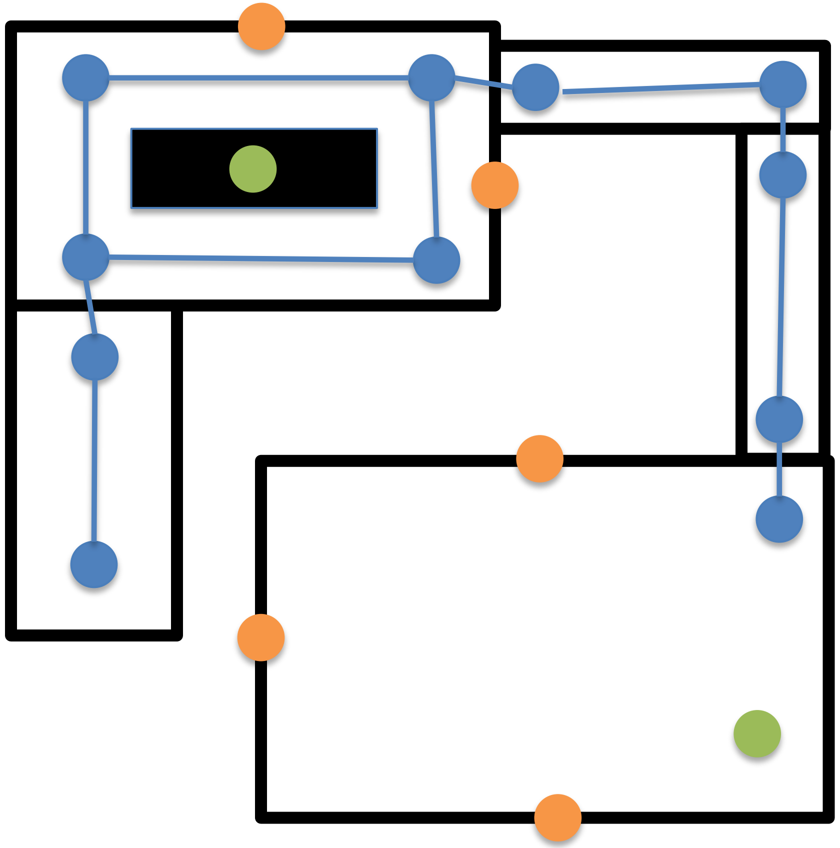


Level

Nodes

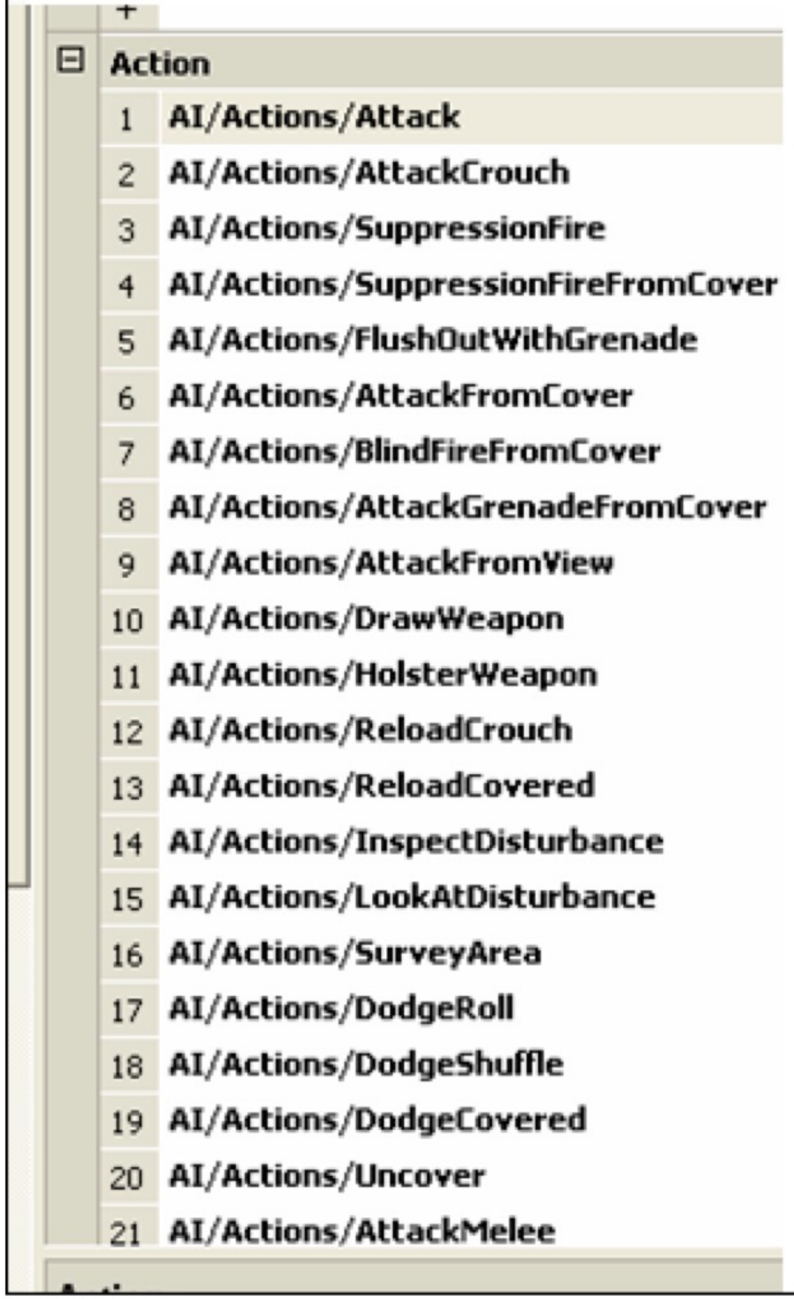
Smart Object Nodes

Mount/Dismount Nodes



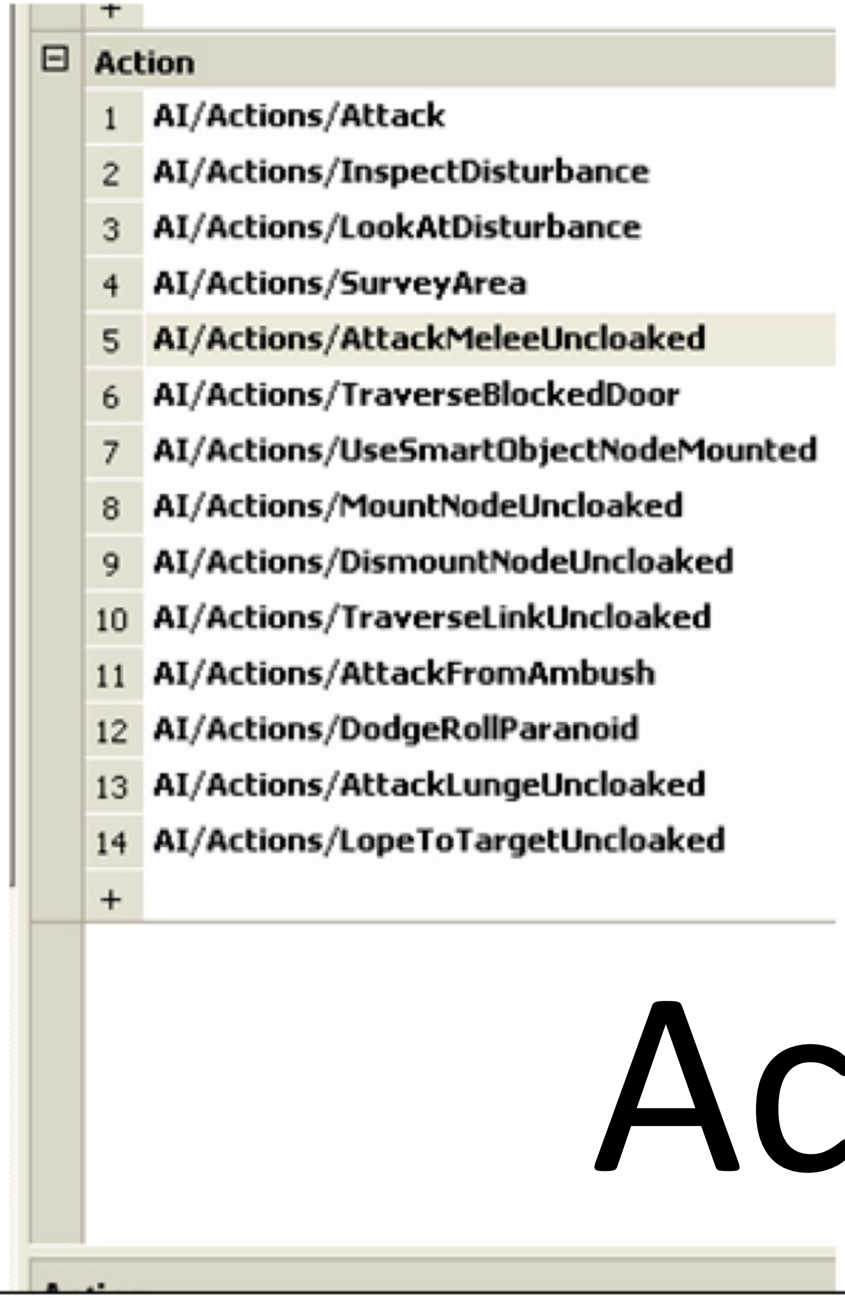
Actions

Soldier



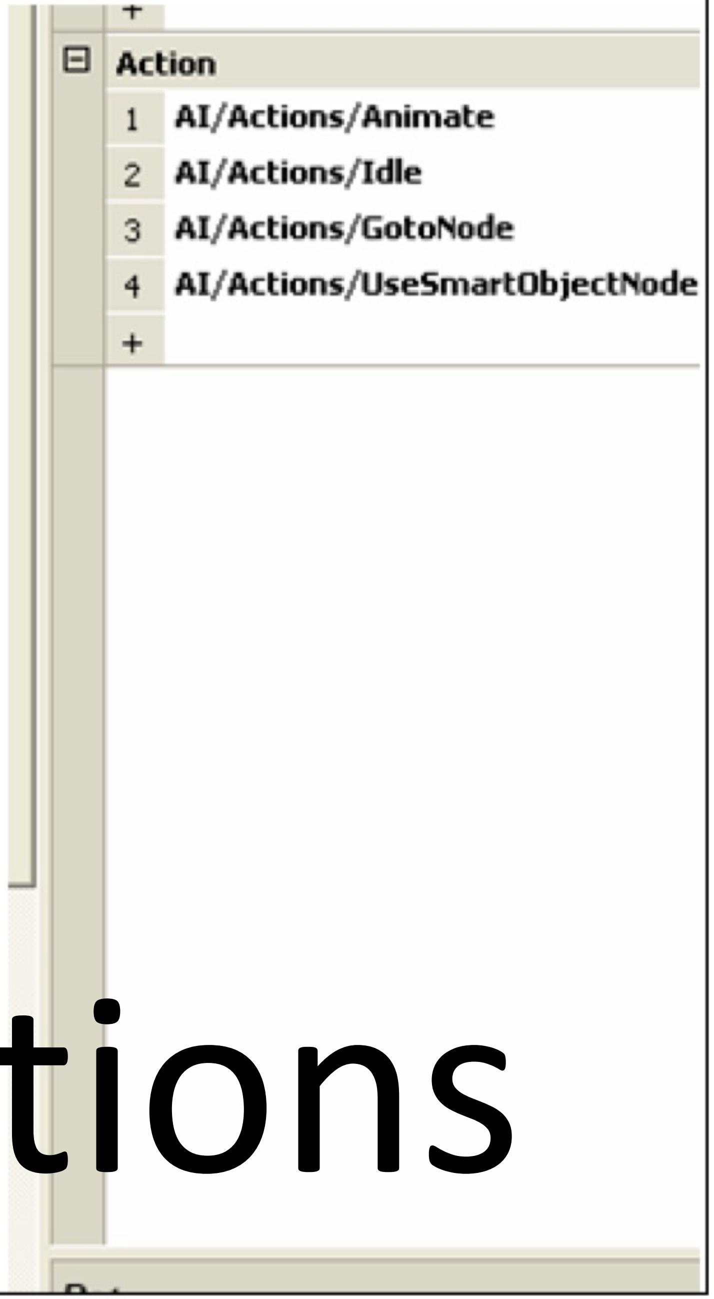
	Action
1	AI/Actions/Attack
2	AI/Actions/AttackCrouch
3	AI/Actions/SuppressionFire
4	AI/Actions/SuppressionFireFromCover
5	AI/Actions/FlushOutWithGrenade
6	AI/Actions/AttackFromCover
7	AI/Actions/BlindFireFromCover
8	AI/Actions/AttackGrenadeFromCover
9	AI/Actions/AttackFromView
10	AI/Actions/DrawWeapon
11	AI/Actions/HolsterWeapon
12	AI/Actions/ReloadCrouch
13	AI/Actions/ReloadCovered
14	AI/Actions/InspectDisturbance
15	AI/Actions/LookAtDisturbance
16	AI/Actions/SurveyArea
17	AI/Actions/DodgeRoll
18	AI/Actions/DodgeShuffle
19	AI/Actions/DodgeCovered
20	AI/Actions/Uncover
21	AI/Actions/AttackMelee

Assassin



	Action
1	AI/Actions/Attack
2	AI/Actions/InspectDisturbance
3	AI/Actions/LookAtDisturbance
4	AI/Actions/SurveyArea
5	AI/Actions/AttackMeleeUncloaked
6	AI/Actions/TraverseBlockedDoor
7	AI/Actions/UseSmartObjectNodeMounted
8	AI/Actions/MountNodeUncloaked
9	AI/Actions/DismountNodeUncloaked
10	AI/Actions/TraverseLinkUncloaked
11	AI/Actions/AttackFromAmbush
12	AI/Actions/DodgeRollParanoid
13	AI/Actions/AttackLungeUncloaked
14	AI/Actions/LopeToTargetUncloaked
+	

Rat

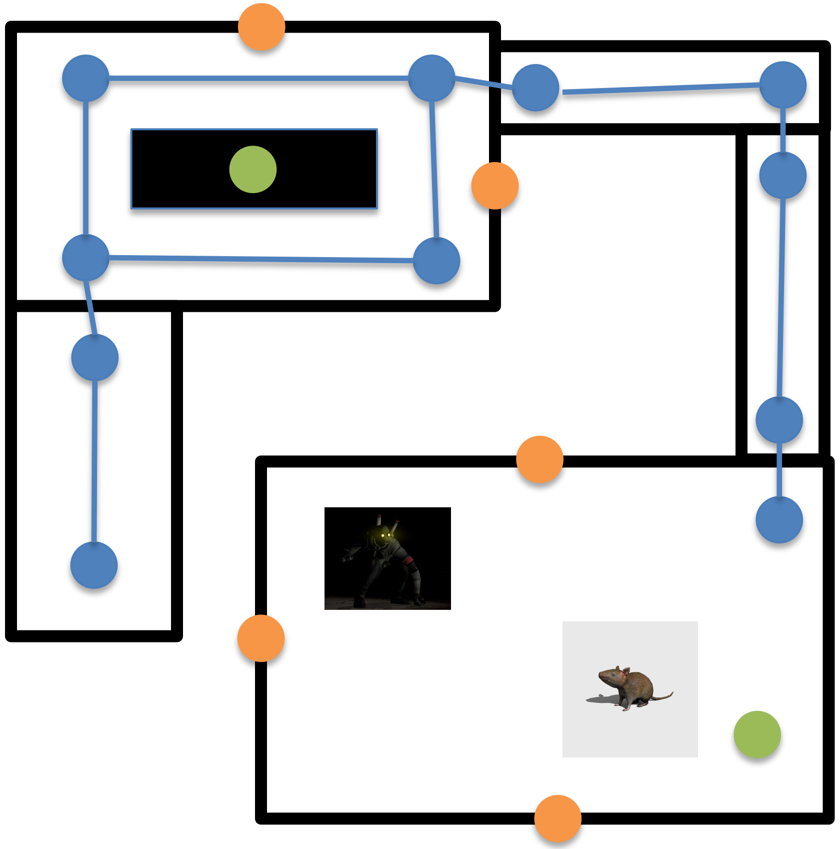


	Action
1	AI/Actions/Animate
2	AI/Actions/Idle
3	AI/Actions/GotoNode
4	AI/Actions/UseSmartObjectNode
+	

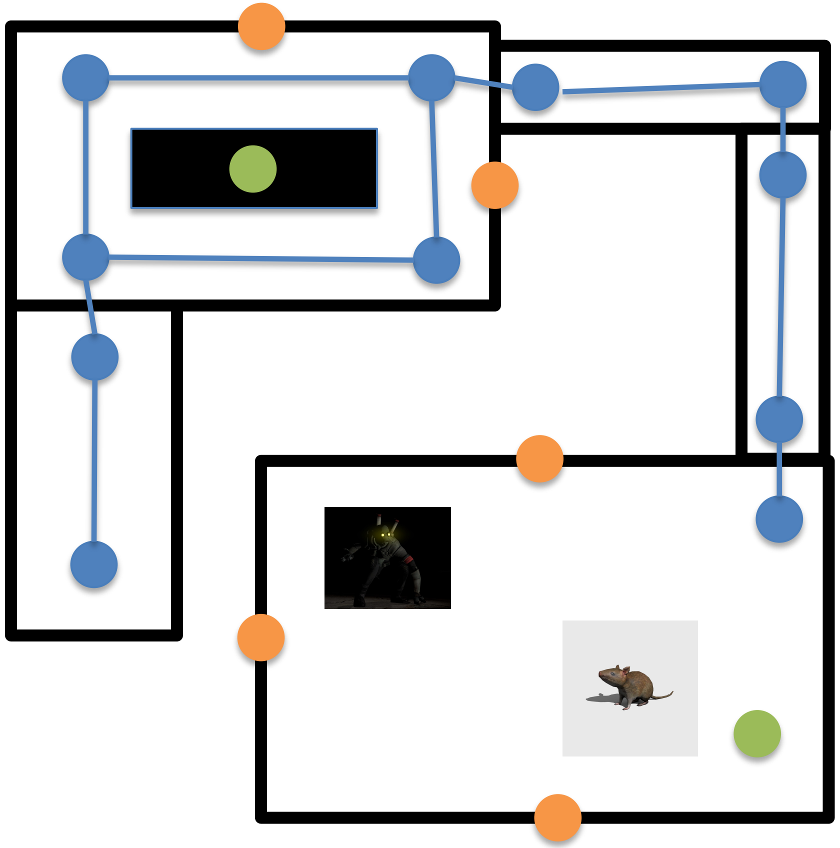
PQ 1: What will happen if we just spawn an assassin onto the map without a goal? What about a rat onto the map without a goal?

https://forms.gle/HZaXAiezv2Rax1BR8

https://tinyurl.com/guz-pq19



Spawn your agents into the level and they'll do <u>Nothing</u>



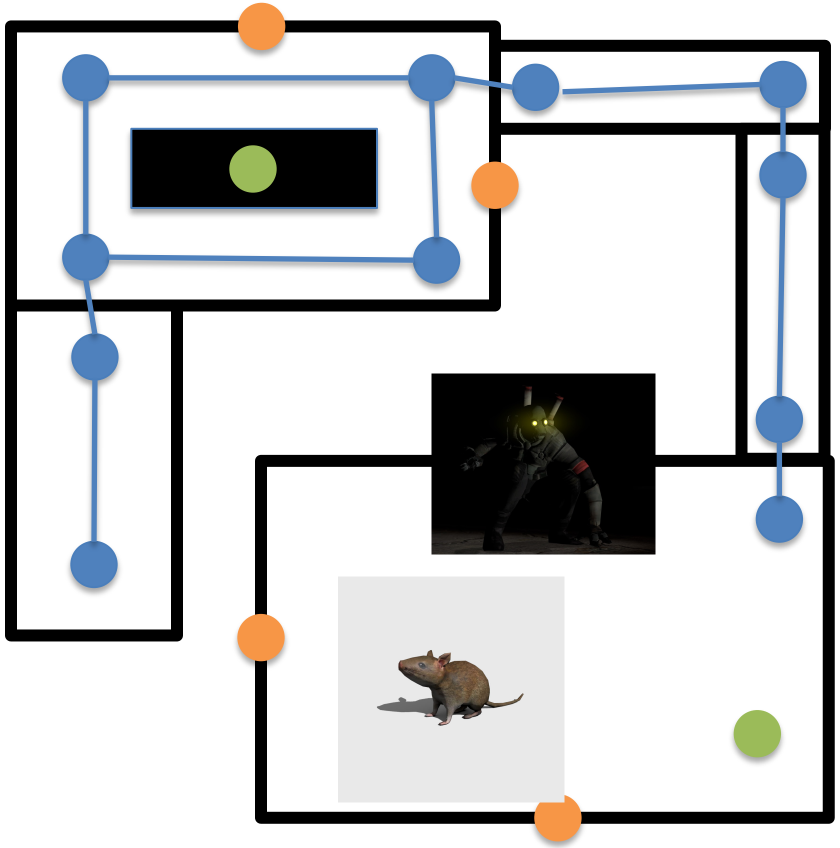
Multiple, Weighted Goals

- Each AI entity in FEAR could be given an arbitrary number of goals.
- Goals were given different priorities.
    - Weights to say the order to try to achieve goals

Example Goals and Priorities

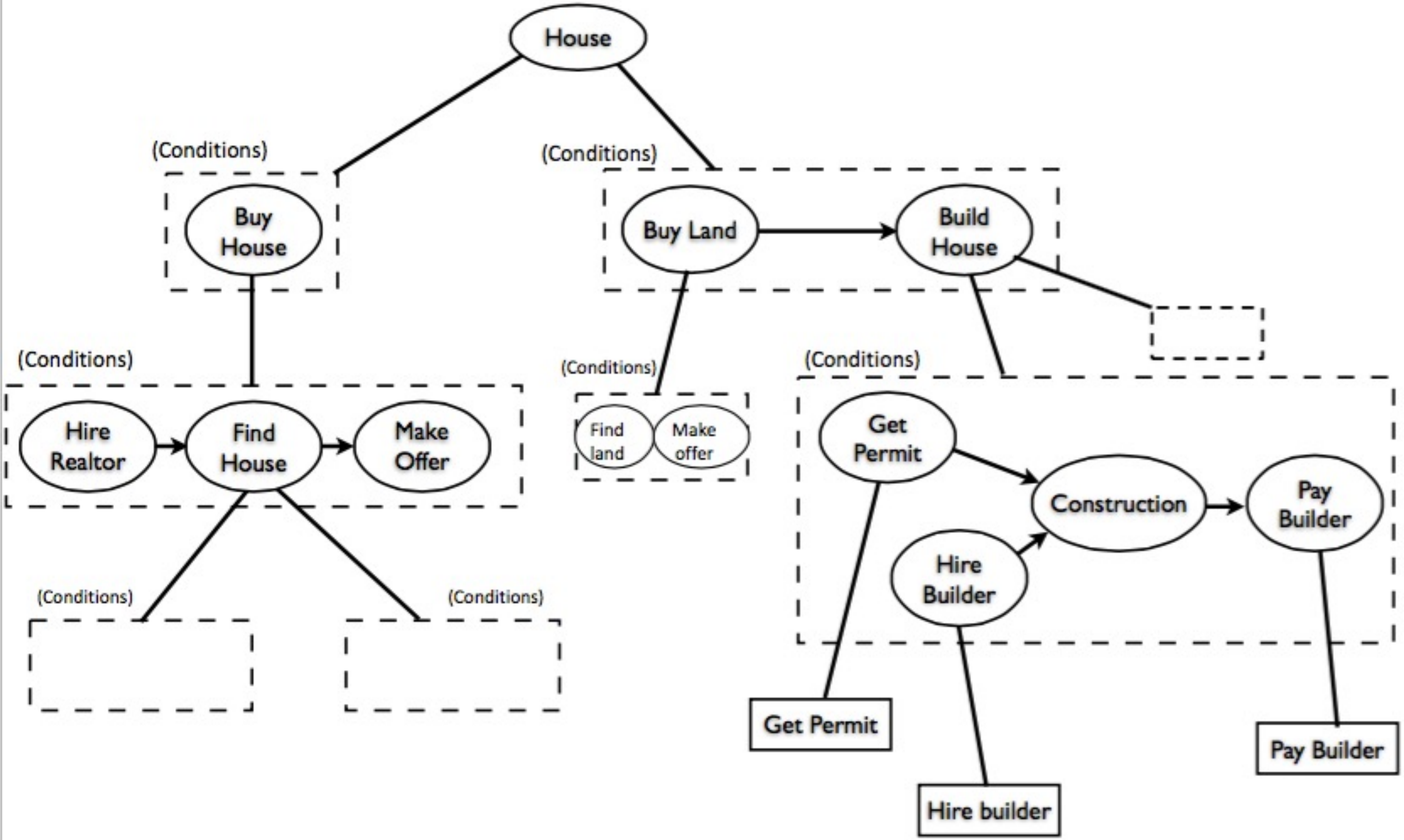
- Survive (0.9)
  - Would lead to the agent dodging incoming fire (DodgeRoll, DodgeShuffle, DodgeCover) or finding cover when exposed.
- Kill_Enemy (0.8)
  - Would lead to the agent using the various attack actions at its disposal.
- Patrol (0.5)
  - Would lead to the agent moving along path network (GoToNode)

Same goals, different behaviour



Squad Behaviors!

- Hand-authored tasks made up of several actions.
- **Get-to-Cover**: Gets all squad members not in cover to cover, while one squad member lays suppression fire.
- **Advance Cover**: Gets all squad members to cover closer to player, while one squad member lays suppression fire.
- **Orderly Advance**: Moves a squad to some position with each squad mate guarding another and the last AI facing backwards
- **Search**: Splits the squads into pairs to search an area.


House
(Conditions)
Buy House
(Conditions)
Buy Land
Build House
(Conditions)
Hire Realtor
Find House
Make Offer
(Conditions)
Find land
Make offer
(Conditions)
Get Permit
Construction
Pay Builder
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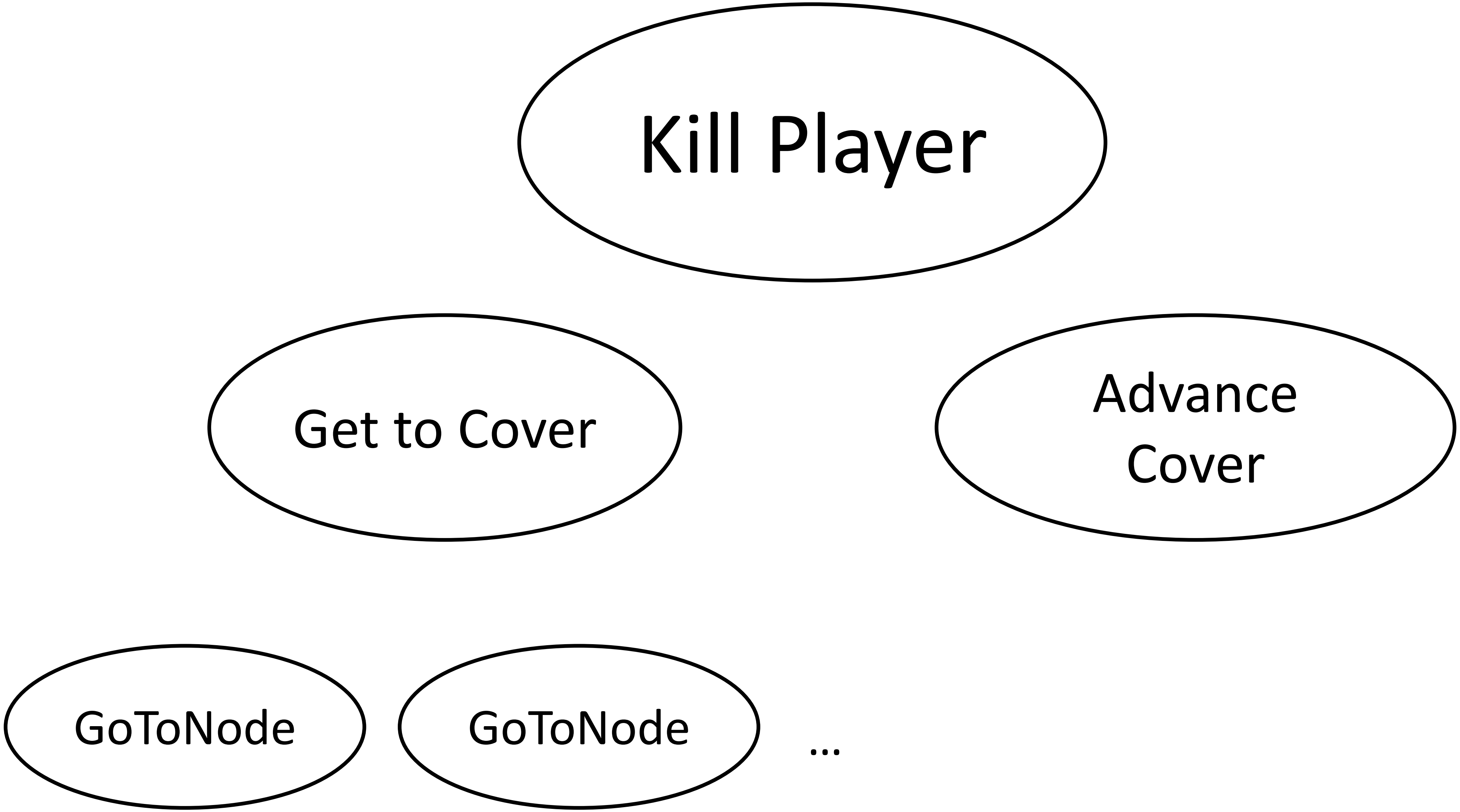
Get Permit
Hire builder
Pay Builder



Kill Player

Get to Cover

Advance Cover

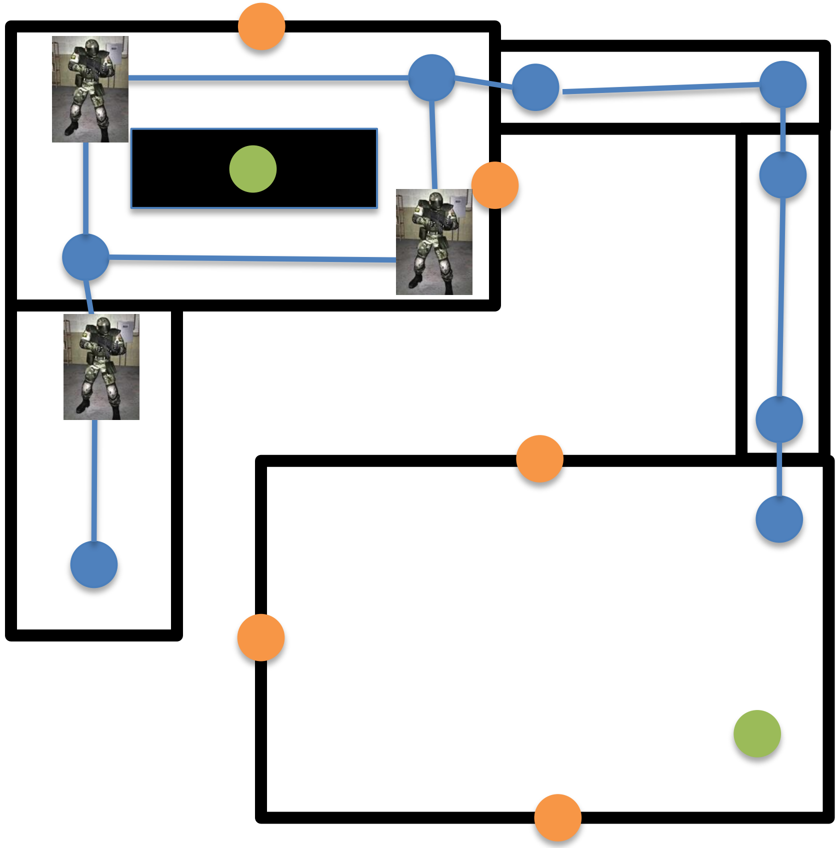
GoToNode

GoToNode

…

All together

World_State
- Player_Nearby=False
- Player_Location_Known = False

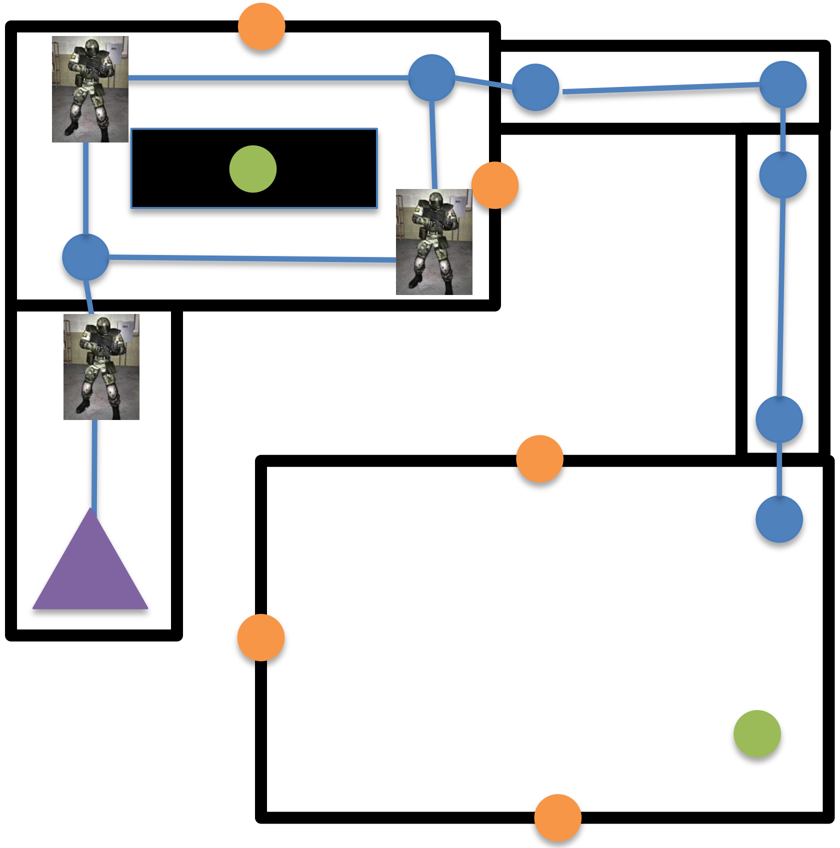


Goals
- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

Time Step = 0

World_State

- Player_Nearby=False
- Player_Location_Known = False



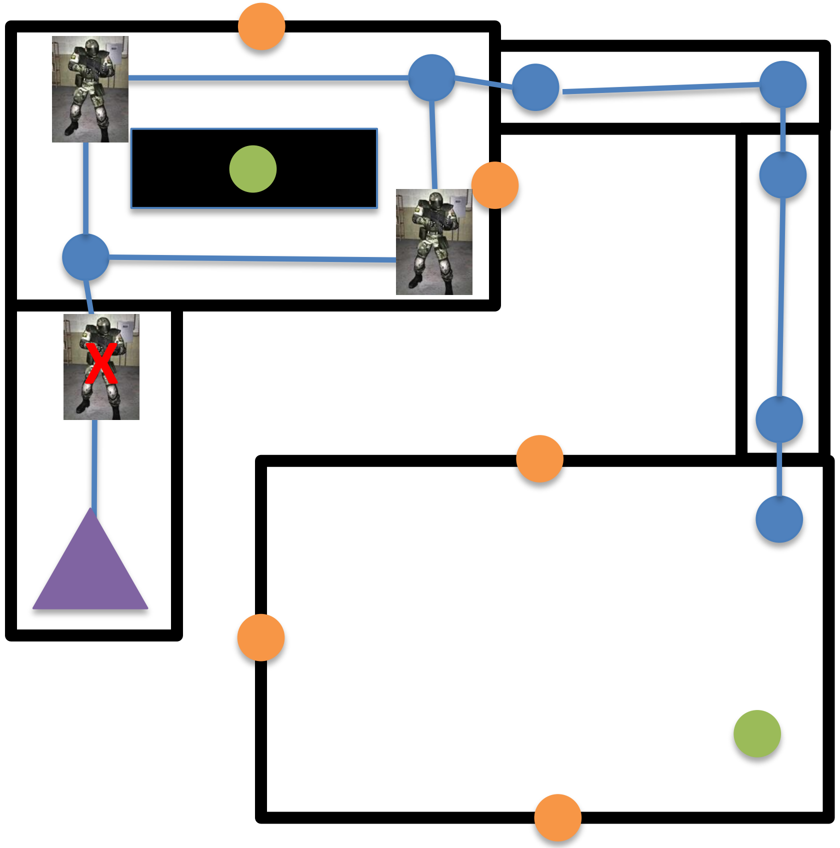
Goals

- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

Time Step = 1

World_State

- Player_Nearby=True
- Player_Location_Known = False

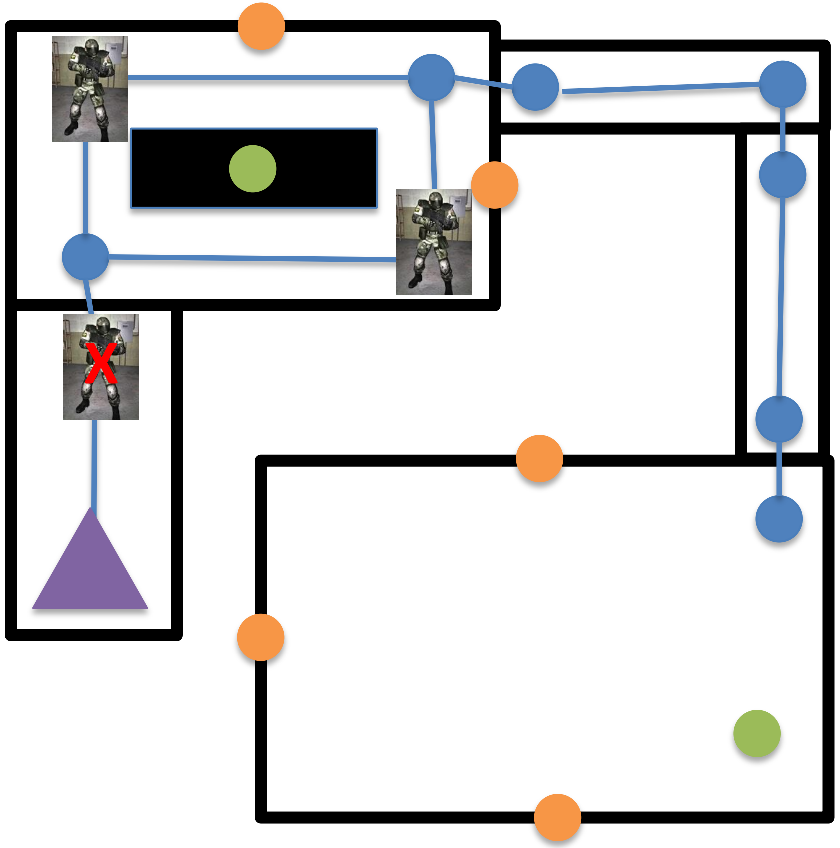


Goals

- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

Time Step = 1

World_State
- Player_Nearby=True
- Player_Location_Known = False



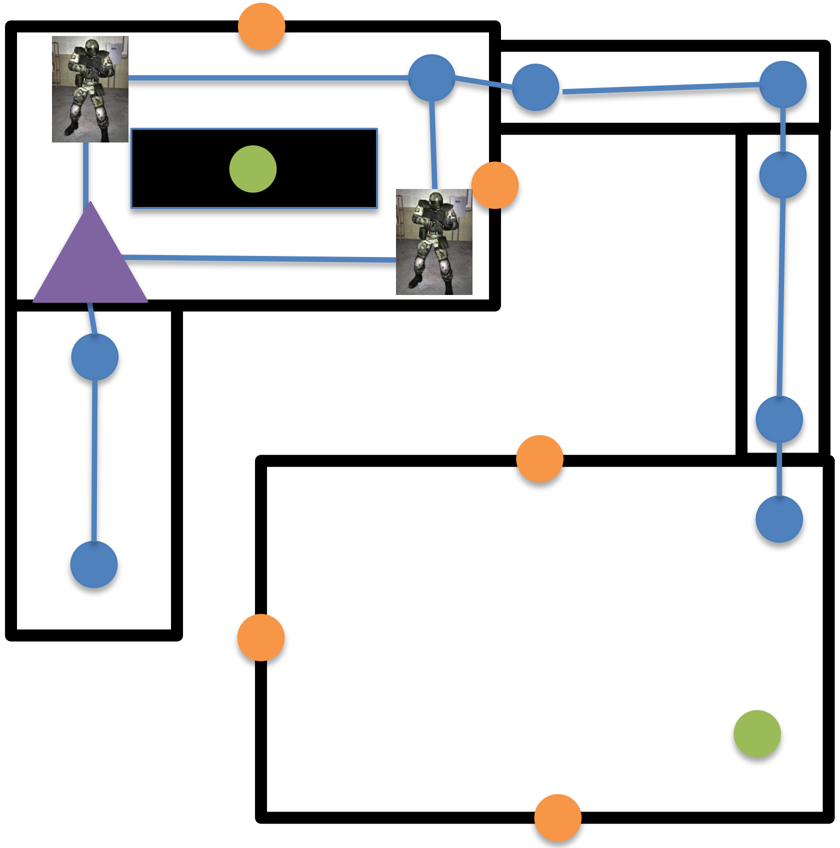
Goals
- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

A* Planner (Goal = Kill_Enemy)
- Search
- Get to Cover
- Advance Cover

Time Step = 2

World_State

- Player_Nearby=True
- Player_Location_Known = True



Goals

- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

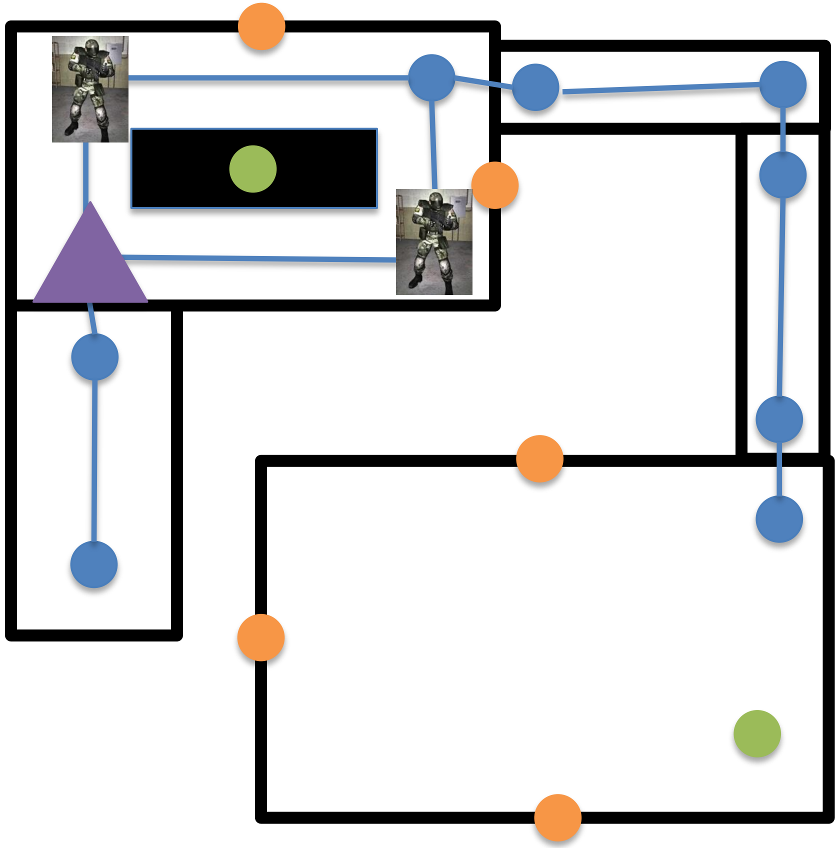
A* Planner (Goal = Kill_Enemy)

- ~~Search~~
- Get to Cover
- Advance Cover

Time Step = 2

World_State

- Player_Nearby=True
- Player_Location_Known = True



Goals

- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

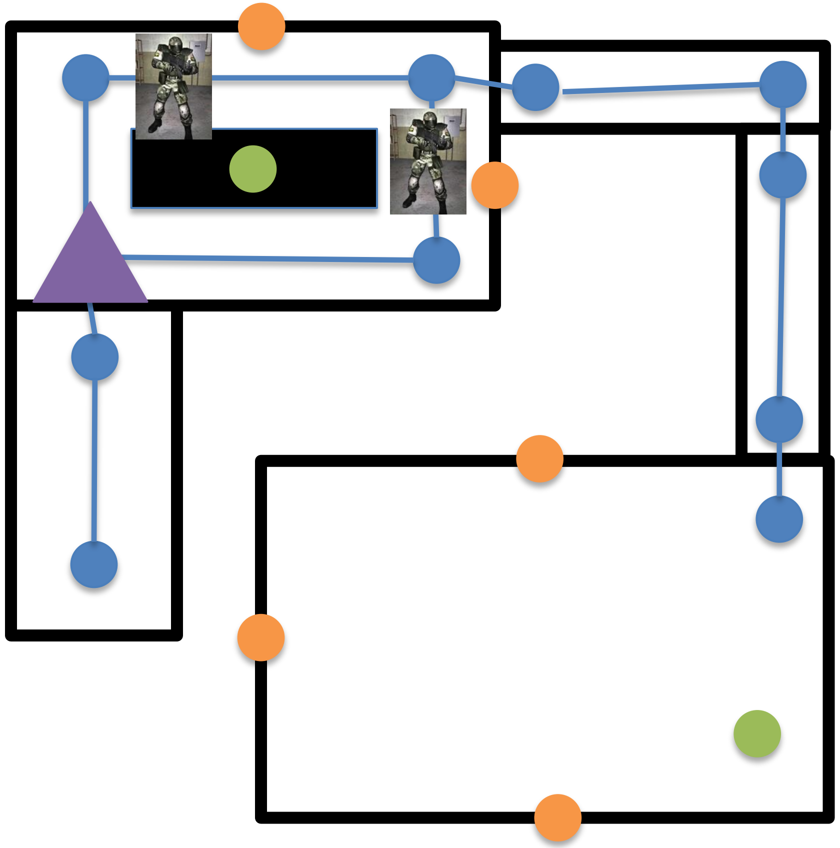
A* Planner (Goal = Kill_Enemy)

- Get to Cover
- Advance Cover

Time Step = 3

World_State

- Player_Nearby=True
- Player_Location_Known = True



Goals

- Survive (0.9)
- Kill_Enemy (0.8)
- Patrol (0.7)

A* Planner (Goal = Kill_Enemy)

- Get to Cover
- Advance Cover

Check back on the video one more time

F.E.A.R AI **(warning a lot of blood**): https://youtu.be/abkDwSDfjqY?t=50 (50 seconds in)

FEAR got away with a single “World State” because of a story excuse that all its soldiers were telepathically linked. How could you implement a similar system without this assumption?

Killzone HTNs

Rather than have a World_State that every agent could reference, each agent tracks their current beliefs about the world.

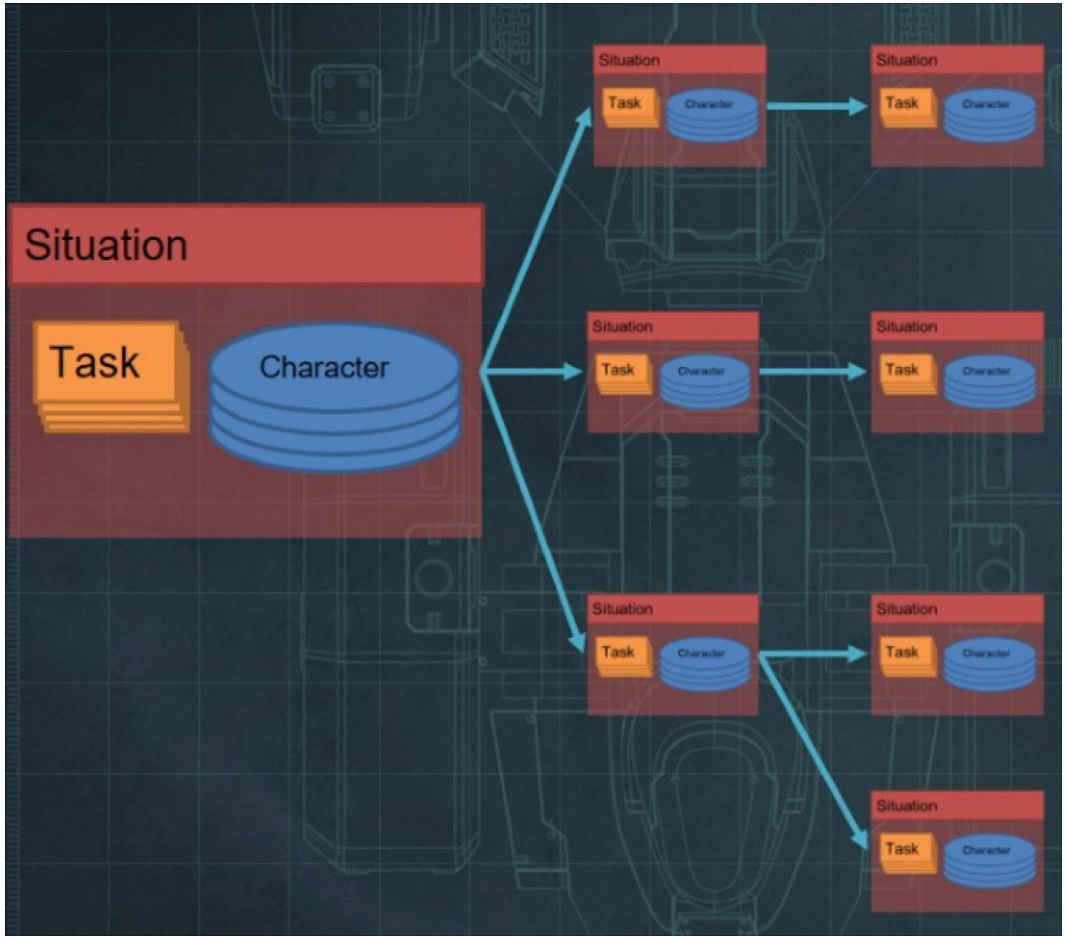
Planning abandoned for Killzone games after 3 (2011).

Even if HTNs only throw away *part* of a plan, that’s still a lot of replanning. How can we adapt to highly dynamic environments?

Left Alive HTNs

Don’t return a single set of actions as a plan, return a tree.

Planning only made use of for mech/vehicle combat.



HTNs Overview

- HTNs faster than non-hierarchical planners on average.
- Takes more authoring than non-hierarchical planning.
  - Actions/tasks at all different levels
  - Gives more designer control, but…
  - Why it was abandoned in later F.E.A.R. games over B trees
- Even with more designer control, hard to convey plans to players (F.E.A.R. barks assigned to each Squad Behavior)

Resources/Optional Readings

- Killzone 1+2 (2011): http://www.gameaipro.com/GameAIPro/GameAIPro_Chapter29_Hierarchical_AI_for_Multiplayer_Bots_in_Killzone_3.pdf
- FEAR 1 (2005): http://alumni.media.mit.edu/~jorkin/gdc2006_orkin_jeff_fear.pdf
- Left Alive (2019): http://www.jp.square-enix.com/tech/library/pdf/GDC2021_ART_HTN.pdf